63

B.C. HYDRO

STIKINE-ISKUT HYDROELECTRIC DEVELOPMENT

FEASIBILITY STUDY

HYDROLOGY, RIVER REGIME AND MORPHOLOGY

HYDROELECTRIC GENERATION PROJECTS DIVISION

Report No. H 1110

October 1981

BOREAL INSTITUTE
LIBRARY

48377

Sept.17 /82
Order No.:
Price: Wf
Acc. No.: B.C. Hydro

Canadian Cataloguing in Publication Data

Main entry under title:

Stikine-Iskut Hydro Electric Development feasibility
study : hydrology, river regime and morphology.

Bibliography: p.
"Report No. 1110".
ISBN 0-7719-8915-6

1. Hydrology - Stikine River (B.C. and Alaska).
2. Hydrology - British Columbia - Iskut River.
3. Stikine River (B.C. and Alaska) - Power
utilization. 4. Iskut (B.C.) - Power utilization.
I. B.C. Hydro. Hydro Electric Generation Projects
Division.

GB1230.B7574 551.48'3'097111 C82-09120-3

LC Class No. B7S74

STIKINE-ISKUT HYDROELECTRIC DEVELOPMENT

FEASIBILITY STUDY

HYDROLOGY, RIVER REGIME AND MORPHOLOGY

CONTENTS

Section Subject Page

SYNOPSIS vi

1.0 INTRODUCTION

1.1 Terms of Reference 1 - 1
1.2 Background and Scope 1 - 5

2.0 AREA DESCRIPTION

2.1 Introduction 2 - 1
2.2 Physiography and Regional Geology 2 - 1
2.3 Climate and Vegetation 2 - 3
2.4 Fluvial Morphology 2 - 4
2.5 Glaciology 2 - 8

3.0 PROPOSED PROJECT DESCRIPTION

3.1 General 3 - 1
3.2 Stikine Site Z 3 - 1
3.3 Tanzilla Project 3 - 5
3.4 More Creek Project 3 - 7
3.5 Forrest Kerr Diversion 3 - 9
3.6 Iskut Canyon 3 - 10

4.0 HYDROLOGY

4.1 Hydrometric and Climatological Data 4 - 1
4.2 Stikine Basin 4 - 3
4.3 Iskut Basin 4 - 22

5.0 SEDIMENTATION

5.1 Suspended-sediment Program 5 - 1
5.2 Suspended-load Transport 5 - 2
5.3 Test Reach Surveys 5 - 3
5.4 Bed-load Computations 5 - 7
5.5 Effects on Downstream Reaches 5 - 9

CONTENTS - (Cont'd)

Section	Subject	Page
5.0	SEDIMENTATION - (Cont'd)	
	5.6 Sedimentation Aspects of the Forrest Kerr Creek Diversion	5 - 15
	5.7 Reservoir Life Estimations	5 - 20
6.0	TEMPERATURE AND ICE REGIME	
	6.1 Temperature	6 - 1
	6.2 Ice Regime	6 - 9
7.0	RECOMMENDATIONS	
	7.1 Hydrology	7 - 1
	7.2 Sedimentation Aspects	7 - 1
	7.3 Temperature and Ice Regime	7 - 2
	REFERENCES	

TABLES

Table No.	
3-1	Principal Project Data
4-1	Available Meteorological Data
4-2	Available Snow Course Data
4-3	Probable Maximum Accumulated Snowfall
4-4	Areas for Flow Generation
4-5	Monthly Average Streamflows at Project Sites
5-1	Suspended Sediment Sampling Summary
5-2	Suspended Sediment Load Summary 1978
5-3	Suspended Sediment Load Summary 1979
5-4	Long-term Suspended Sediment Load Calculations - Stikine River Basin
5-5	Long-term Suspended Sediment Load Calculations - Iskut River Basin

CONTENTS - (Cont'd)

TABLES - (Cont'd)

Table No.	
5-6	Suspended Sediment Load Balance
5-7	Bed Load Computation Summary
5-8	Estimations of Reservoir Life

PLATES

Plate No.	
2-1	Study Area
2-2	Glacier Location
2-3	Yuri Glacier
2-4	Andrei and Forrest Kerr Glaciers
2-5	Profiles - Stikine River
2-6	Profiles - Iskut River
2-7	Isohyet Map
2-8	Drainage Area - Stikine River
2-9	Drainage Area - Iskut River
2-10	Drainage Area - More Creek
3-1	Stikine Project Locations
3-2	Iskut Project Locations
3-3	Reservoir Filling Curves
3-4	Forrest Kerr Diversion Dam - Location Plan
4-1	Available Streamflow Data
4-2	Hydrometric and Climatological Networks

CONTENTS - (Cont'd)

PLATES - (Cont'd)

Plate No.	
4-3	Daily Flow Probabilities
4-4	Mean Monthly Flows
4-5	Mean Monthly Water Levels
4-6	Flow Duration Curves
4-7	Flood Frequency Curves
4-8	UBC Watershed Model Calibration Plot
4-9	Probable Maximum Flood Hydrographs
5-1	Grainsize Distribution, Suspended Sediment
5-2	Suspended Sediment Rating Curves
5-3	Suspended Sediment Load
5-4	More Creek Test Reach, Cross Sections
5-5	Upper Iskut River Test Reach, Cross Sections
5-6	Lower Iskut River Test Reach, Cross Sections
5-7	Lower Stikine River Test Reach, Cross Sections
5-8	Grainsize Distribution, Bed Material
5-9	Forrest Kerr Creek Diversion Profile
5-10	Discharge, Slope and Grainsize Data for Braided Rivers
5-11	Post-project Flood Frequency Curves
5-12	Test Reach Profiles
6-1	Air Temperature Data
6-2	Water Temperature Envelopes - Peace River Basin
6-3	Water Temperature Envelopes - Stikine River Basin
6-4	Water Temperature Envelopes - Iskut River Basin

CONTENTS - (Cont'd)

PHOTOS

Photo No.	
1	Upstream View along the Stikine River near the Upstream End of the Proposed Site Z Reservoir
2	Grand Canyon of the Stikine River, Upstream View
3	Stikine River above Chutine River, Upstream View
4	Stikine River Lower Test Reach above the Scud River
5	Iskut River Upper Test Reach, Upstream View
6	Iskut Canyon, Upstream View
7	Iskut River below Iskut Canyon Damsite, Upstream View
8	Iskut River Lower Test Reach, Downstream View
9	More Creek, South Fork, Upstream View
10	Forrest Kerr Creek Diversion Route, Looking from Forrest Kerr Creek towards the South Fork of More Creek

SYNOPSIS

The Hydrology, River Regime and Morphology Studies of the Stikine-Iskut Development described in this report were carried out for two major reasons. Firstly, to provide information for use in the project feasibility study and secondly, to provide information for the environmental impact analysis.

Field and office studies were carried out to provide preliminary estimates for each proposed project of long-term flow patterns, flood frequencies, probable maximum floods and useful reservoir life.

Field and office studies were also carried out to provide preliminary estimates of the regulated flow regime, channel morphology changes and water temperature changes that would result from the construction of the project.

The significant findings of these studies are listed below:

1. The following tabulation highlights the important hydrologic features for economic and design considerations.

Site	Average Annual Flow (m^3/s)	15-year Return Period Flood (m^3/s)	PMF Peak Inflow (m^3/s)	Spillway Design Discharge (m^3/s)	Useful Reservoir Life (Years)
Site Z	286.5	2440	9175	7645	2200
Tanzilla	291.8	2480	7645	7645	-
Iskut Canyon	251.4	1630	6286	5680	180
More Creek	69.4	500	2676	1580	1600

2. The river reaches downstream of the project sites will likely be affected by changes in flow regime, channel morphology and water temperature.

The flow changes on both rivers are likely to result in a reduction of approximately 50 percent in summer flows and an increase ranging from 300 to 500 percent in winter flows at the major project sites. Near the mouth of the Stikine at the USGS gauge the approximate effect on flows is likely to be a 25 percent reduction in summer flows and a 100 percent increase in winter flows. This would translate into a .8 m decrease in summer water level and a .8 m increase in the winter levels. The downstream braided sections of the Iskut would probably become less braided as side channels silt up and the main channel widens and deepens. A similar process would occur on the Stikine but to a much lesser extent. The downstream water temperatures resulting from the proposed regulation would probably be cooler in summer and warmer in winter.

This report was prepared largely during 1980 on the basis of the data available at that time (basically up to the end of 1979, except for snow course data, the latest of which was dated April 1980). An extensive field data collection program has been established which will provide additional data for environmental, design and operational studies as required during the preliminary design stage of the development. It is intended that addendum reports be prepared in the future at such intervals as the additional data warrant.

SECTION 1.0 - INTRODUCTION

1.1 TERMS OF REFERENCE

The terms of reference for the Hydrology Section of the Feasibility Studies for the Stikine and Iskut developments are in two parts: one for the Stikine River (assignment no. 478-058) and one for the Iskut River (assignment no. 478-059) and both are dated 19 July 1978. In the terms of reference, as in the previous studies, the Tanzilla Site was referred to as Site C and Iskut Canyon was referred to as Iskut Site B.

The terms of reference for the Stikine River are as follows:

"1. The proposed scheme of development comprises two basic projects in the following site areas:

Stikine Site Z	-	combined dam and powerhouse site, with major storage reservoir for flow regulation.
Stikine Site C	-	Dam, providing for run-of-river operation only, with powerhouse located 6 km downstream.

In addition, very limited study of a low head project downstream from the Site C powerhouse and upstream of the Klastline River may be undertaken.

2. Assess whether the estimates of the probable maximum floods developed during the overview studies can be improved upon at this time, recognizing the current paucity of meteorological data for the basin (the meteorological network is to be expanded and maintained under general Assignment No. 476-121 to permit future improvement of the PMF estimates). Carry out additional PMF studies by mathematical model or regional analysis if it is deemed possible to make a significant improvement in the quality of the P.M.F. estimates. For spillway configurations selected by Project Development and using reservoir operating criteria to be agreed upon, carry out flood routing studies to permit selection of the spillway design floods.

1.1 TERMS OF REFERENCE - (Cont'd)

3. Review and update overview study flood frequency information for purposes of selecting the design construction flood peak for each project. Flood peaks of suitable frequency will be selected jointly by Project Development and Hydrology personnel considering project flood risk criteria for the particular river works selected for each project layout.

4. Assess effect of changes in the river flow regime at downstream locations due to flow regulation by the Site Z project with capacity factors of 50, 60 and 70 percent. The corresponding river stages at these downstream locations are to be compared for conditions with and without the Stikine River development. Power flow and spill data will be provided by Project Development personnel.

5. Continue ice observations along the Stikine River and study local ice conditions in the damsite areas to assist in determining design criteria for diversion facilities required during construction. Provide a preliminary assessment of the effect of flow regulation on the ice regime within the Site Z reservoir area and downstream of Site Z, in terms of time and pattern of freeze-up and break-up and length of open water downstream from the development.

6. Carry out a program of suspended-sediment sampling at appropriate Water Survey of Canada gauges both upstream and downstream of the potential hydroelectric developments. Study and provide a preliminary assessment of the amount of sediment inflow into the reservoirs and the estimated life of the reservoirs. Study and provide a general assessment of the effects of upstream sediment impoundment and flow regulation on the morphology of downstream reaches of the river and the estuary, considered with and without the effects from the Iskut River development. Study and provide a more detailed assessment of the effects of flow regulation at a specific downstream reach to be selected relative to salmon fishery studies.

7. Arrange for installation and maintenance of water temperature recorders at all WSC stations on the Stikine River. Study and provide a preliminary assessment of the effect of the impoundment of flow regulation on temperature changes in the downstream reaches of the river and estuary, considered with and without the effects from the Iskut River development."

1.1 TERMS OF REFERENCE - (Cont'd)

The terms of reference for the Iskut River are as follows:

1. The proposed scheme of development comprises two basic projects in the following site areas:

   Iskut Site B - Dam, providing storage for some flow regulation, with powerhouse located 2 1/2 km downstream.

   More Creek Site - Combined dam and powerhouse site, with storage reservoir for regulation of More Creek and Forrest Kerr Creek flows. This project includes a diversion dam which provides for complete diversion of Forrest Kerr Creek at a point approximately 27 km upstream of its confluence with the Iskut River.

2. Assess whether the estimates of probable maximum flood developed during the overview studies can be improved upon at this time, recognizing the current paucity of meteorological data for the Iskut basin (the meteorological network is to be expanded and maintained under general Assignment No. 476-121 to permit future improvement of the PMF estimates). Carry out additional PMF studies by mathematical model or regional analysis if it is deemed possible to make a significant improvement in the quality of the PMF estimates considering initial results from the Iskut Glaciological Study (under Assignment No. 746-121). For spillway configurations selected by Project Development and using reservoir operating criteria to be agreed upon, carry out flood routing studies to permit selection of the spillway design floods.

3. Review and update overview study flood frequency information for purposes of selecting the design construction flood peak for each project. Flood peaks of suitable frequency will be selected jointly by Project Development and Hydrology personnel considering project flood risk criteria for the particular river works selected for each project layout. Special attention is to be given to the initial results from the Iskut Glaciological Study in selecting the diversion design floods.

1.1 TERMS OF REFERENCE - (Cont'd)

4. From initial Iskut Glaciological Study results, estimate the contribution of ablation to streamflows at the More Creek site and at Iskut Site B. Assess the reliability of the streamflows previously developed for these two projects and used for the power studies, considering potential long term variations in glacier runoff.

5. Assess effect of changes in the river flow regime at downstream locations due to flow regulations by the Site B and More Creek projects with capacity factors of 50, 60 and 70 percent. The corresponding river stages at these downstream locations are to be compared for conditions with and without the Iskut River development. Power flow and spill data will be provided by Project Development personnel.

6. Continue ice observations along the Iskut River and study local ice conditions in the damsite areas to assist in determining design criteria for diversion facilities required during construction. Provide a preliminary assessment of the effect of flow regulation on the ice regime within the Site B and More Creek reservoirs and downstream to the Stikine River, in terms of time and pattern of freeze-up and break-up and length of open water downstream from the development.

7. Carry out a program of suspended-sediment sampling at appropriate Water Survey of Canada gauges both upstream and downstream of the potential hydroelectric developments. Carry out river surveys and sampling of bed materials at suitable locations upstream of the More Creek and Site B projects and along the Forrest Kerr Creek diversion route. Study and provide a preliminary assessment of the amount of suspended-sediment and bed-load inflow into the reservoirs and the estimated life of these reservoirs. Study and provide a general assessment of the effects of upstream sediment impoundment and flow regulation on the morphology of the downstream reaches of the Iskut and Stikine rivers and the Stikine River estuary, considered in conjunction with the effects from the Stikine River development.

8. Arrange for installation and maintenance of water temperature recorders at all WSC stations on the Iskut River. Study and provide a preliminary assessment of the effect of the impoundment and flow regulation on temperature changes in the downstream reaches of the river and estuary, considered in conjunction with the effects from the Stikine River development."

1.2 BACKGROUND AND SCOPE

A number of reports have predated the present one which have, in part, dealt with the hydrology, river regime or morphology of the Stikine and Iskut basins. The most recent ones are:

Montreal Engineering Company Ltd. April 1972. Provincial Power Study for the B.C. Provincial Energy Board.

Hydroelectric Design Division, B.C. Hydro. January 1978. Hydroelectric Development of the Stikine River Overview Study.

Hydroelectric Design Division, B.C. Hydro. January 1978. Hydroelectric Development of the Iskut River Overview Study.

Hydroelectric Design Division, B.C. Hydro. September 1977. Stikine Development, Project Overview Study, Hydrology.

Hydroelectric Design Division, B.C. Hydro. March 1978. Iskut Development, Project Overview Study, Hydrology.

The present study serves as a basic reference to the Hydroelectric Design Division report, "Stikine-Iskut Hydroelectric Development Feasibility Study," dated March 1980.

For the present study the projects in the Iskut basin and in the Stikine basin are considered in one volume due to their interdependence.

The scope of the work done for this report include field and office studies by B.C. Hydro and their consultants and in co-operation with various Federal and Provincial and U.S. Government departments. Principal work items described in detail within the body of this report are:

1.2 BACKGROUND AND SCOPE - (Cont'd)

1. A suspended-sediment and bed-load transport field program.

   a. A field program carried out in the summers of 1978/79 included measurement of suspended-sediment at various locations in the basin. A bed material sampling program was conducted concurrently. Additional suspended-sediment samples were collected by the Water Survey of Canada.

   b. Surveying and monitoring of four test reach areas in 1979. The survey work was carried out by Underhill Engineering Ltd.

2. Office studies to estimate the bed-load movement and total suspended load.

3. Analysis of available hydrologic and meteorologic data to determine long-term flow regime and Probable Maximum Flood.

4. Initiation and maintenance of a snow course and meteorological network.

5. Initiation and maintenance of a water temperature monitoring program.

6. Glaciology program being carried out in the basin by the National Hydrology Research Institute, Snow and Ice Division.

7. Monitoring of river ice conditions in the basin.

SECTION 2.0 - AREA DESCRIPTION

2.1 INTRODUCTION

The Stikine-Iskut river system drains an area of 52 100 km^2 in northwestern British Columbia (and a small portion of the Alaska Panhandle, Plate 2-1) and enters the Pacific Ocean just north of Wrangell, Alaska. The Stikine River flows south and west for 600 km from its headwaters in the Skeena Mountains. The Iskut River flows for 210 km from Thatue Mountain to its confluence with the Stikine 11 km upstream of the Canada-U.S. border. At its confluence with the Stikine the Iskut River drainage area totals 9380 km^2. Profiles of the two rivers appear on Plates 2-5 and 2-6.

2.2 PHYSIOGRAPHY AND REGIONAL GEOLOGY

The Stikine-Iskut study area lies within the Western and Interior Systems of the Cordillera region (Holland, 1976). The western system includes the primary area called the Coast Mountain Area, a secondary area called the Coast Mountains and is enclosed by the tertiary area referred to as the Boundary Ranges. Of the Interior System, the basin includes parts of the primary area called the Central Plateau and Mountain Area. The Stikine River drains most of the secondary area called the Stikine Plateau and smaller parts of the Cassiar Mountains and the Skeena Mountains. Tertiary areas in the basin include the Tahltan Highland, the Nahlin Plateau, the Tanzilla Plateau, the Klastline Plateau, the Stikine Ranges and the Spatsizi Plateau.

The Boundary Ranges of the Interior System extend northwest through the study area and consist of a core of plutonic rocks flanked on the east by volcanic and sedimentary rocks. These mountains are very rugged and contain large regions that are covered with glaciers and snowfields with some isolated peaks protruding. Glacier features such as cirques, hanging valleys and oversteepened slopes are common. The highest local peak is Mount Ratz (3136 m) with numerous other peaks over 2100 m. Peaks below 2000 m are rounded from erosion by ice sheets that once covered the mountain ranges to that elevation. Deposits of marine origin occur at elevations up to 30 m above present sea level; terraces and benches found 150 m above sea level may be delta deposits of marine origin.

The Stikine Plateau of the Interior System is subdivided into seven units having distinct geographic and geologic characteristics. Of these, five are drained in whole, or in part, by the Stikine River. In general the Stikine Plateau is an erosion surface rather than one built up through deposition of sedimentary or volcanic materials. During the Pliocene, there was a general uplift of western North America and, in particular, an uplift of the Stikine Plateau to over 2000 m. This uplift rejuvenated the erosive power of the streams. During the Pleistocene, the plateau was covered with glacial ice which resulted in disorganization of many of the drainage systems. The plateau contains a number of centres of volcanic activity. These have been active in the Tertiary, Pleistocene and Recent periods.

The Tahltan Highland is drained in part by the Stikine and is a transition zone between the Boundary Ranges and the plateaus of the interior. It is 10 to 50 km wide, the widest area being where the Stikine River crosses. There are several sharp peaks and a series of volcanic cones including Mount Edziza (2789 m) which rise above the dissected upland. Cinder cones unmarred by erosion, are a conspicuous feature of the Edziza-Spectrum Range area. Pleistocene glaciation was extensive in the area and numerous glaciers still exist.

The Nahlin Plateau is drained in part by the Stikine River. The area is dominated by the great shield volcano of Level Mountain (2164 m). Streams and late stage glaciation have dissected some of the gently dipped slopes.

2.2 PHYSIOGRAPHY AND GEOLOGY - (Cont'd)

The Tanzilla Plateau is a partially dissected erosion surface which reaches a height of 1935 m at Snow Peak on the watershed divide of the Tuya, Tanzilla and Dease rivers. It is an area of widely flaring valleys, rounded ridges and peaks passing eastward into serrate peaks and higher uplands of the Cassiar Mountains.

The Klastline Plateau is a rolling upland surface which represents the late Tertiary erosion surface. The northern boundary of the plateau is the Stikine River including the area known as the Grand Canyon of the Stikine. The plateau lies at 1500 m with peaks rising to 2290 m and it is extensively dissected.

The Spatsizi Plateau is a gently rolling upland, dissected by wide, drift-filled valleys representing the remnants of the late Tertiary erosion surface. The region was covered by Pleistocene ice sheets to a height of 2135 m, some of which moved out from the plateau in a northerly and northeasterly direction.

2.3 CLIMATE AND VEGETATION

The Coast Mountains in the vicinity of the mouth of the Stikine River reach to heights of 3000 m and act as a barrier to the movement of Pacific maritime air from the semi-permanent Aleutian low. The valley of the Iskut and Stikine are too narrow and tortuous to permit the infiltration of more than a small amount of moist Pacific air into the Stikine Plateau region. The isohyet map (Plate 2-7) shows a steep precipitation gradient from the mouth of the Stikine up the Stikine valley to Telegraph Creek where the dry interior continental climate begins to prevail. Precipitation on the Iskut is heavy up to the More Creek confluence where the interior climate begins to prevail.

The vegetation in the Stikine basin changes fairly predictably with rainfall. The bars and banks of the lower Stikine River

2.3 CLIMATE AND VEGETATION - (Cont'd)

above high water levels contain a heavy growth of willows, cranberry bushes and other shrubs with a scattering of large cottonwood and evergreen trees. The lower slopes of the wet coastal climate area are covered by a forest of spruce, hemlock and fir. This coastal climate area has a tree line around 1200 m. Proceeding upstream, the rainfall begins to drop off and around Little Canyon the vegetation begins to thin out and the undergrowth disappears. At the upper end of the basin on the Stikine Plateau, the forests are sparse with subalpine meadows and tundra predominating.

2.4 FLUVIAL MORPHOLOGY

Both the Stikine and Iskut valleys were formed by glacial action during the ice ages, the last of which ended only some 10 000 years ago. Major valley glaciers do not require a continuous downhill gradient and they tend to leave resistant parts of the valley floor high while excavating deep basins elsewhere. This, combined with the effects of moraines and lava flows blocking some old river channels accounts for the present irregular river profiles. The over-deepened basins have been filled and are now generally occupied by braided or split, unstable gravel bed reaches while bedrock knobs, moraines and lava flows are dissected by deeply entrenched, often canyon-like valleys. Isostatic rebound has exposed older deltaic deposits as terraces up to 150 m above sea level in the lower valley reaches.

The headwaters of the Stikine River lie in the Omineca, Cassiar and Skeena mountains and on the Spatsizi Plateau (Plate 2-1). At the head of the proposed Site Z reservoir, the river flows in a trench-like valley cut by fluvial action into the Stikine Plateau surface. The river channel can be described as split and highly unstable, with extensive gravel bars. Lateral development of the channel is frequently confined by impingement on high, erodible and unstable valley walls (Photo 1). Some 20 km downstream of the confluence with the Klappan River which drains the northern Skeena Mountains, the

2.4 FLUVIAL MORPHOLOGY - (Cont'd)

Stikine enters the 50 km long Grand Canyon cut into resistant Triassic volcanics (Photo 2). The two proposed damsites are in this canyon. Downstream of the Tuya River confluence the canyon gradually widens but the river remains deeply incised and confined by bedrock banks to the vicinity of Telegraph Creek. Mess Creek, a major left bank tributary some 2 km downstream of Telegraph Creek, brings a large load of coarse gravel to the Stikine, but the Stikine River is capable of moving it without aggradation. For the next 40 km to the Chutine River confluence, the Stikine River flows in a relatively straight, partially-entrenched single channel on the floor of a very broad valley (Photo 3). The river is bordered mainly by glacial deposits but there are also some fluvial terraces, alluvial fans and small floodplain segments. The channel bed is composed primarily of gravel and coarser material. Several boulder or bedrock rapids occur along this reach.

At about the Chutine River confluence, the Stikine River enters the Coast Mountains and over the next 120 km it is joined by many short, steep tributaries carrying large and coarse sediment loads. In response, the Stikine River morphology changes to a split or almost braided and unstable pattern of multiple channels (Photo 4). Single channel segments occur occasionally at sites where the river is either confined by large, active fans or at the foot of short rock canyons. At one location the Stikine is confined by the terminal moraines of the Great Glacier which still reaches the valley floor. The split-to-braided morphology extends to the U.S. border and beyond.

The Iskut River is by far the largest tributary to the Stikine. It originates on mountain slopes in the Klastline Plateau and flows through Eddontenajon, Tatogga, Kinaskan and Natadesleen lakes. After following a southerly course for 60 km in a large valley between the Spectrum Range on the west and the Klappan Range on the east, the river turns westward at the confluence with Ningunsaw River to cross the Coast Mountains.

Along the first 50 km of its course, from Kinaskan Lake to the confluence with More Creek, the Iskut flows in a shallow and narrow, stream-cut valley on the floor of a very broad valley. There are frequent rapids on bedrock or on boulders and the bed material is generally coarse. Many tributaries join the Iskut along this reach and most appear to carry large sediment loads. From the More Creek confluence downstream, the Iskut River has a 20 km long alluvial reach. The river flows in a wide valley but the channel zone with associated island and floodplain segments are generally no more than 300 to 500 m wide. The channel pattern is mostly split-to-braided, and occasionally confined by the valley walls (Photo 5). Over a few short reaches, the river is forced into a single channel by the alluvial fans of major tributaries. The reservoir of the Iskut Canyon project would lie in this reach.

This upper braided reach ends abruptly 4 km upstream of Forrest Kerr Creek, where the Iskut River enters a very narrow (30 m or less) bedrock canyon cut through Triassic andesites and Recent lava flows (Photo 6). The Iskut Canyon dam would block this canyon approximately 2 km below the Forrest Kerr Creek confluence, with the powerhouse 2 km further downstream where the canyon opens up into a somewhat wider (100 to 150 m) trench-like valley, still bordered by vertical rock walls (Photo 7). This incised reach is approximately 18 km long. The valley floor is almost entirely taken up by the river channel, but there are also some small alluvial fans, debris cones and floodplain segments. The river flows in a confined single channel on a bed of coarse gravel. The channel alignment is relatively straight although there is one prominent complete meander loop. Being deeply incised, this loop is as old as the valley trench itself.

Several glacial tributaries join the Iskut River along this reach; McLymont and Snippaker creeks being the largest ones with drainage areas of 252 km^2 and 281 km^2 respectively. Some 4 km downstream of the Snippaker Creek confluence, the trench-like valley ends abruptly and the Iskut River spreads out onto the floor of a broad valley. The channel morphology changes from a narrow, stable, entrenched single channel, to a wide, highly braided, unstable and aggrading system of multiple channels (Photo 8). This braided pattern persists over a reach of approximately 40 km, along which the Craig River and several short, steep proglacial streams with large sediment loads join the Iskut River. Over its last 8 km, upstream from its entry into the Stikine River, the Iskut reverts back to a reasonably stable channel associated with a broad genetic floodplain.

Both the 40 km braided reach and the last, short, single channel or split reach are probably slowly aggrading. The rapid downstream decline in grain size, which can only be obtained through selective deposition, and the complete absence of fluvial terraces support such a conclusion. The same also applies to the short Stikine River reach from the mouth of the Iskut River to Frederick Sound. Since isostatic rebound is also well established for this area, with latest data indicating a rate of rise around 1 m per century (Vanicek and Nagy, 1980), it appears that the forward growth of the Stikine delta is sufficiently large to take up the added vertical drop through forward extension of the river channel.

Forrest Kerr Creek and More Creek, the two tributaries to the Iskut that would be affected by the project, are both glacier fed mountain streams. They are generally characterized by broad, highly braided and unstable channels on the floor of wide, steep-sided valleys (Photo 9). Often the unvegetated channel zone reaches from valley wall to valley wall but there are also significant areas of wooded or marshy floodplain. Occasionally, the braided channel zones are confined by large alluvial fans and there are also a few bedrock canyon reaches. It is in one of these bedrock canyons where the More Creek damsite would be located.

2.5 GLACIOLOGY

(a) General

Runoff from glaciers represent a significant portion of the total runoff upstream of the Iskut Project site and of the lower sections of the Stikine and Iskut rivers. The extent of glacierized area can be seen on Plate 2-2.

The Snow and Ice Division of the National Hydrology Research Institute (NHRI) and B.C. Hydro have jointly carried out a glaciology program on the Iskut River. This program was begun in 1978 and concentrates on the glaciers above the More Creek damsite.

The objectives of the program are to:

1. Establish long-term estimates for the glacier mass balance.
2. Establish estimates of probable maximum rates of glacier runoff for use in defining the spillway design discharge.
3. Establish estimates of glacier contribution to suspended sediment and bed-load.

A glaciological field program was established including the installation of a snow accumulation and ablation stake network and a meteorological station as well as a regular reconnaissance program. Analysis of the data collected has been done by B.C. Hydro and NHRI. The data was collected on three glaciers tentatively named Andrei, Yuri and Forrest Kerr. Detailed maps of these glaciers appear on Plates 2-3 and 2-4, and their general location in the basin can be seen on Plate 2-2. Plates 2-3 and 2-4 also show estimates of the glacier position in 1965 and the line of maximum glacier advance.

2.5 GLACIOLOGY - (Cont'd)

(b) Correction of Long-term Runoff Estimates for Glacier Mass Balance

Results of the 1978 and 1979 glaciological studies have been used in making tentative estimates of the corrections that would have to be applied in order to provide unbiased long-term runoff estimates of Forrest Kerr and More creeks and Iskut River above Snippaker Creek for use in the estimation of the power studies of the proposed Iskut Canyon and More Creek power developments. The power studies are discussed further in Section 9.2(b) and in detail in the report "Stikine Iskut Feasibility Study, March 1980".

The following calculations have been made:

Comparison of Estimated Loss of Glacier Ice with Measured River Discharges at WSC Gauges

	1978 $m^3 \times 10^6$	1979 $m^3 \times 10^6$
Forrest Kerr Creek Basin	2 June-12 September	4 May-28 September
Loss of glacier ice	215.364	140.459
Runoff at Gauge 08CG006	768.045	911.714
Percent of runoff from loss of glacier ice	28%	15.4%
More Creek Basin	5 June-21 September	2 May-28 September
Loss of glacier ice	149.607	129.94
Runoff at Gauge 08CG005	993.161	1370.632
Percent of runoff from loss of glacier ice	15.1%	9.5%

Glacier Volumetric Changes since the Recent Maximum Advance - Assumed to have Occurred in 1880

Figs. 2-3 and 2-4 show the extent of the tongues of Andrei and Forrest Kerr and Yuri Glaciers in the Iskut basin obtained from 1965 aerial photographs, with contour lines obtained

2.5 GLACIOLOGY - (Cont'd)

by the use of a Wild 47 Plotter. Superimposed are contours of the glaciers in 1880 which have been inferred from the positions of front and lateral moraines.

From these two maps NHRI made estimates of the net volumetric change in the glaciers (i.e. volume of ice lost through ablation) from 1880 to 1965.

The following calculations have been made to estimate long-term losses of glacier ice (1880-1965) for comparison with the losses computed for 1978 and 1979.

Forrest Kerr Creek

1.	Ice loss 1880 to 1965 for 4 km^2 map sheet	$1923 \times 10^6 m^3$
2.	Average year ice loss for 4 km^2 map sheet	$22.6 \times 10^6 m^3$
3.	Average year ice loss for total Forrest Kerr glacier area	$22.6 \times 10^6 \times 6.084 =$ $137.498 \times 10^6 m^3/yr =$ $4.36\ m^3/s$
4.	Long-term (1940-1975) flows of Forrest Kerr Creek	$20.7\ m^3/s$
5.	Ratio of ice loss to long-term runoff = $\frac{4.36}{20.7}$	21.1%
6.	a. 1978 value of percent runoff from loss of glacier ice (see above)	28.0%
	b. 1979 value of percent runoff from loss of glacier ice (see above)	15.4%

More Creek

1.	Ice loss 1880 to 1965 for 4 km^2 map sheet	$60.3 \times 10^6 m^3$

2.5 GLACIOLOGY - (Cont'd)

2.	Average year ice loss for 4 km^2 map sheet	$0.7 \times 10^6 m^3$
3.	Average year ice loss for total More Creek glacier area	$0.7 \times 10^6 \times 124.67 =$ $87.269 \times 10^6 m^3/yr =$ $2.77\ m^3/s$
4.	Long-term (1940-75) flows of More Creek	$48.7\ m^3/s$
5.	Ratio of ice loss to long-term runoff = $\frac{2.77}{48.7}$	5.7%
6.	a. 1978 value of percent runoff from loss of glacier ice (see above)	15.1%
	b. 1979 value of percent runoff from loss of glacier ice (see above)	9.5%

Notes:

1. Item 5 for Forrest Kerr Creek, compared with Items 6a and 6b, indicates that the ice loss for 1978 was above the long-term average ice loss while that for 1979 was below the long-term average.

   Item 5 for More Creek, compared with Items 6a and 6b, indicates that the ice losses for both 1978 and 1979 were above the long-term average.

2. These corrections to the long-term runoff values of Forrest Kerr and More creeks would need to be confirmed by additional mass-balance studies carried out in 1980 and subsequent years.

3. The possibility of evaluating long-term runoff values for Forrest Kerr and More creeks by the use of proxy data generated from glacier-core or tree-ring measurements should be investigated.

4. Similar computations should be carried out for the Iskut River above Snippaker Creek, which would probably require an evaluation of the total glacier area in the drainage area above Gauge No. 08CG004.

(c) Investigations of High Rates of Glacial Runoff

It is recognized that high rates of runoff from the Forrest Kerr and More Creek basins, and the Iskut River basin above Snippaker Creek, are caused by combinations of meteorological events which produce rapid melting of snow and ice with coincident direct precipitation on both glacierized and ice-free areas.

Judging from the hydrographs of the gauges on the three streams, it appears that the greatest volumes of runoff (i.e. mean monthly discharge) are recorded in the months of July and August but the highest rates of runoff (i.e. instantaneous peak discharge) are recorded in the months of October and early November. This may be because in spring and early summer solar radiation is relatively high in magnitude, but the albedo (reflectivity) of the glacier surface is also high, and wind velocities and air temperatures are lower. In mid-summer, radiation is slightly diminished, but the average albedo has decreased markedly, making radiation a highly effective melting agent. During fall storms, the combination of warm maritime air and strong winds causes high rates of melt due to the exchange of heat from the air. Radiation from the sun is decreased at this time of the year but long-wave back radiation from warm clouds may contribute significant amounts of energy for ice and snow melt.

The extremely high peak flows recorded on the Iskut River below Johnson River in October 1961, November 1969, October 1974, October 1978 and October 1979 were undoubtedly caused by fall storms which brought extensive saturated warm air masses into the basin and produced rapid rates of early snow (and possibly ice) melt which augmented the runoff from rain.

2.5 GLACIOLOGY - (Cont'd)

Streamflow records in the Forrest Kerr and More Creek basins date only from 1972, and continuous climatological records in the glacier areas date only from June 1979 with the establishment of the Forrest Kerr Glacier Climatological Station adjacent to Andrei Glacier.

This information can be used to construct a hydrologic model of the Forrest Kerr basin which can be calibrated from historic climatological and streamflow data. To date the high runoff of 10-15 October 1979 represents the only event for which continuous temperature, precipitation, streamflow and (possibly wind) data have been recorded.

SECTION 3.0 - PROPOSED PROJECT DESCRIPTION

3.1 GENERAL

Four power sites and one diversion dam are proposed for hydroelectric development in the Stikine-Iskut basin. The location of these projects can be seen on Plate 2-1. Details of the proposed projects can be found in Section 9-12 of the report "Stikine-Iskut Feasibility Study", March 1980. The following Section outlines the significant hydraulic and design features of the projects. While in the Feasibility Study two dam types are considered, in the following subsections only the principal proposed dam type is outlined.

3.2 STIKINE SITE Z

(a) General

Plate 3-1 shows the locations of the two projects on the Stikine River, and the approximate extent of the Site Z reservoir at El. 794.0 (maximum normal level), and of the Tanzilla reservoir at El. 531.0 (maximum normal level).

Table 3-1 presents principal project data for all proposed projects on the Stikine and Iskut rivers. The significant features of the Stikine Site Z project are:

A concrete arch dam built across the Stikine canyon, and an earthfill dam built across an abandoned channel of the Stikine River on the north bank connected by a concrete gravity dam would create a reservoir with a total storage of 6.7 bcm (which represents about 75 percent of the 1965 to 1978 mean annual runoff)

3.2 STIKINE SITE Z - (Cont'd)

The live storage volume would be 3.8 bcm or approximately 42 percent of the mean annual runoff volume.

(b) Spill Facilities

The spillway discharge facilities would consist of:

1. Service outlet valves in the arch dam - with a release capacity of 2000 m^3/s at maximum flood reservoir level of El. 797.0; and 1500 m^3/s at minimum normal reservoir level of El. 749.0.

2. An auxiliary spillway with three radial gates built at the north end of the arch dam to discharge a maximum of 5645 m^3/s down a steep chute and over a flip bucket into the canyon downstream from the arch dam.

The valves would be used to discharge flood flows of moderate magnitude (up to their release capacity of 2000 m^3/s), and the auxiliary spillway would be used to pass flood flows in excess of 2000 m^3/s (up to their release capacity of 5645 m^3/s). The combined valves and auxilary spillway would thus be capable of passing the spillway design discharge of 7645 m^3/s from a Probable Maximum Flood with a 3.0 m flood surcharge (see Plate 4-9).

(c) Diversion Facilities

During the period when the Site Z dam would be under construction, the flow of the Stikine River would be diverted through a tunnel designed to pass the 15-year return period diversion flood peak of 2440 m^3/s under free flow conditions. At the end of the diversion period, closure of the tunnel would be expected to cause the reservoir to rise from El. 570 to El. 620, after which time the river flow could be passed through the low level outlet valves in the arch dam.

3.2 STIKINE SITE Z - (Cont'd)

Reservoir filling would be expected to commence in November and outflows from the reservoir would be controlled by operating the three low level valves to pass, in each month from November to May, the minimum recorded daily average flow from that month. This would ensure some filling in each month and also that flows in the river channel downstream from the project would be no lower than they had been at some time under natural conditions. During the months from June to September, releases from the outlet facilities would be arbitrarily limited to 75 m^3/s, which is approximately 25 percent of the long-term flow of the Stikine River at Site Z. Flows in the river downstream from Site Z would be augmented by inflows from tributaries such as the Tanzilla, Klastline, Tuya and Tahltan rivers with the result that flows at Telegraph Creek would range between 130 and 900 m^3/s compared with natural June to September flows ranging between 300 and 2000 m^3/s.

Reservoir filling curves for Stikine Site Z project from typical dry, average and wet years, represented by the minimum, average and maximum years of historic record are shown in Plate 3-3.

(d) Power Facilities

The power intakes would be located within the concrete gravity dam on the north bank and comprise three gated openings leading to concrete-lined penstocks which would feed three Francis turbines in an underground powerhouse from which the flows would be returned to the river through a tailrace tunnel.

(e) Reservoir Operations

Operation of the combined power units at Site Z and Tanzilla was studied with the SHRUMO (Simulated Hydro Resources Under Monthly Operation) computer program using a 35-year sequence of historical and correlated streamflows data for the period July

1940 to June 1975. The energy output from the combined Stikine and Iskut projects was assumed to form an addition to the B.C. Hydro integrated system load.

Monthly power outflows, spills and reservoir levels resulting from operation of the Stikine projects as part of the integrated system were estimated by SHRUMO, and indicated that for a maximum reservoir level of El. 794 a drawdown of 45 m to El. 749, expected flow utilization for power generation would be 94 percent with a capacity factor of about 65 percent.

For assessing the effects of the operation of the Stikine projects on the river channel downstream from the projects it was necessary to simulate daily rather than monthly flows. This was done by routing historic Stikine River daily flows for the period of record through the Site Z reservoir by the RESROUT program and using the SHRUMO monthly power outflows for Site Z to estimate daily reservoir level changes and spills.

These routings showed the Site Z reservoir increasing from minimum levels at or above El. 749 in early May to maximum levels at or near El. 794 by mid-August, and spills of up to 350 m^3/s in such wet years as 1974. The daily outflow probabilities for the Site Z reservoir (Plate 4-3) for the period of record have been estimated by the HYSUM computer program which evaluates the maximum and minimum daily outflows and the outflows with exceedance probabilities of 25 percent, 50 percent and 75 percent. As may be seen in Plate 4-3 the outflows from Site Z reservoir would correspond to the SHRUMO monthly power flows of about 280 m^3/s in the months from January to June and November to December but would rise to as much as 800 m^3/s in July, 750 m^3/s in August, 850 m^3/s in September and 700 m^3/s in October.

3.2 STIKINE SITE Z - (Cont'd)

Other Daily Flow Probabilities shown in Plate 4-3 for the Stikine at Telegraph Creek, Butterfly Creek and Wrangell for both natural and regulated conditions show the effects of the tributary inflows in modifying the flows of the Stikine River.

3.3 TANZILLA PROJECT

(a) General

Plate 3-1 shows the location of the two projects on the Stikine River. Table 3-1 presents the principal data for all of the projects. As shown in this table, the significant features of the Stikine-Tanzilla project are as follows:

A concrete arch dam would be built across the Stikine Canyon. The reservoir created would have a total storage of 0.8 bcm (which represents about 9 percent of the mean annual runoff). The project would have no live storage.

(b) Spill Facilities

The spillway discharge facilities would consist of:

1. Service outlet valves in the arch dam - with a release capacity of 2000 m^3/s at maximum flood reservoir level of El. 534.0 or 1950 m^3/s at normal reservoir level of El. 531.

2. An auxiliary spillway located at the top centre of the arch dam. It would have a discharge capacity of 5645 m^3/s.

The valves would be used to discharge flood flows of moderate magnitude (up to their release capacity of 2000 m^3/s), and the auxiliary spillway would be used to pass flood flows in excess of 2000 m^3/s (up to their release capacity of 5645 m^3/s). The combined valves and spillway would be capable of passing the

3.3 TANZILLA PROJECT - (Cont'd)

peak outflow of 7645 m^3/s. The discharge from Site Z resulting from the Probable Maximum Flood is assumed to pass through the Tanzilla reservoir with no routing.

(c) Diversion Facilities

A single diversion tunnel would be provided to pass the 15-year return period flood of 2480 m^3/s under free flow conditions.

Filling of the reservoir would be expected to take place concurrently with filling of the Site Z reservoir. The three low level valves would be used to pass, in each month from November to May, the minimum recorded daily average flow for that month. This would insure under all historical runoff some filling in each month and also that flows in the river channel would be no lower than they had been at some time under natural conditions.

During the months from May to September, releases from the outlet facilities would be arbitrarily limited to 75 m^3/s which is approximately 25 percent of the long-term average annual flow of the Stikine River at the project site. Flows in the river downstream would be augmented by inflows from tributaries such as the Tanzilla, Klastline, Tuya and Tahltan rivers with the result that flows at Telegraph Creek would range between 130 and 900 m^3/s compared with natural June to September flows ranging between 300 and 2000 m^3/s.

(d) Power Facilities

The power intake would comprise a bell mouth inlet and, 50 m downstream, a vertical concrete level shaft housing two hydraulically-operated fixed wheel gates. The power tunnel would be approximately 4.7 km long from inlet to surge shaft. The surge shaft approximately 75 m high would be constructed in the rock near the downstream end of the power tunnel. There would be three Francis turbines in an underground powerhouse from which the water would flow through the tailrace tunnel and into the river.

(e) Reservoir Operation

The Tanzilla project would be operated as a run of the river powerplant and therefore the outflows from the Tanzilla reservoir would be approximately equal to the outflows from Site Z reservoir. The operation of the combined Site Z and Tanzilla projects is discussed in Section 3.2(d).

3.4 MORE CREEK PROJECT

(a) General

Plate 3-1 shows the locations of the three projects on the Iskut River, and the approximate extent of the More Creek reservoir at El. 528 (maximum normal level).

Table 3-1 presents principal project data for all proposed projects on the Stikine and Iskut rivers. As shown in Table 3-1, the significant hydraulic features of the More Creek project are as follows:

A concrete arch dam built across the More Creek canyon 500 m upstream of the canyon outlet. The reservoir created would have a total storage of 2.0 bcm (which represents about 95 percent of the present average annual runoff volume after diversion). The live storage volume would be 1.3 bcm or approximately 62 percent of the average runoff volume after diversion.

3.4 MORE CREEK PROJECT - (Cont'd)

(b) Spill Facilities

The spillway discharge facilities would consist of:

1. Service outlet valves in the arch dam - with a release capacity of 330 m^3/s at maximum flood reservoir level of 531 m and a release capacity of 250 m^3/s at minimum reservoir level of 488 m.

2. An auxiliary spillway, located at the top centre of the arch dam. It would have a discharge capacity of 1250 m^3/s at maximum flood reservoir level.

The valves would be used to pass flood flows of moderate magnitude (up to their release capacity of 330 m^3/s). The combined valves and spillway would be capable of passing the Probable Maximum Flood routed outflow of 1580 m^3/s.

(c) Diversion Facilities

A single diversion tunnel is provided through the right abutment to pass the 15-year return period flood of 500 m^3/s under free flow conditions (Plate 4-7).

Filling of the reservoir would be expected to start in November as shown in Plate 3-3. Prior to closure of the diversion tunnel at More Creek, the Forrest Kerr diversion dam would be closed so that the extra water from Forrest Kerr Creek would be available for reservoir filling. The low level outlets would be used during reservoir filling to pass, in each month from November to May, the minimum recorded daily average flow for that month. During the months from May to September, releases from the reservoir would be arbitrarily limited to 18 m^3/s which is approximately 25 percent of the long-term average annual flow at the More Creek site.

3.4 MORE CREEK PROJECT - (Cont'd)

(d) Power Facilities

The power intake comprises a 60 m high concrete gate shaft housing, a hydraulically-operated fixed wheel service gate. The penstock would be approximately 380 m in length and 5 m in diameter. It would lead to an underground powerhouse located in the north side of the canyon containing one Francis turbine. The turbine flow would be discharged back to the river via a tailrace tunnel.

(e) Reservoir Operation

Operation of the Iskut projects was studied with the use of the SHRUMO computer program using a 35-year sequence of historical and correlated streamflow data for the period July 1940 to June 1975. The program estimated outflows, spills and reservoir levels on a monthly basis and indicated that for a maximum reservoir level of El. 528 a drawdown of 40 m would result in a flow utilization for power generation of virtually 100 percent with a capacity factor of 65 percent.

Daily simulations of the More Creek project were made using the monthly outflows as determined by the SHRUMO program. These simulations indicate that the reservoir tended to be almost full (El. 528) around September to October and nearly empty (El. 488) in spring (April and May). The relatively large reservoir and regular runoff pattern would allow for very high flow utilization and even in wet years such as 1974, only minor spills might be needed.

3.5 FORREST KERR DIVERSION

(a) General

Plate 2-1 shows the location of the Forrest Kerr Diversion site and Plate 3-2 is an area map of the three projects proposed for the Iskut basin. The purpose of this project is to

3.5 FORREST KERR DIVERSION - (Cont'd)

divert the upper end of Forrest Kerr Creek into the More Creek reservoir. A 37 m high 200 m long earthfill dam would create a small reservoir from which water would be diverted through a channel excavated into a low divide to the south fork of More Creek and from there into the More Creek reservoir. The mean annual diversion flow is expected to be about 20.7 m^3/s which is an increase to the More Creek flows of about 43 percent. A detailed plan of this project site appears as Plate 3-4.

3.6 ISKUT CANYON

(a) General

Plate 3-2 shows the proposed layout of the three projects on the Iskut River and the approximate extent of the Iskut Canyon reservoir at full supply level (El. 347).

Table 3-1 presents the principal project data for the proposed projects. As shown in Table 3-1, the significant features of the Iskut Canyon project are as follows:

A concrete arch dam would be built across a narrow, deep gorge. On both sides of the canyon, the arch dam would be connected to concrete gravity dams which would be connected to earthfill wing dams. The reservoir created would have a total storage of 3.8 bcm (which represents 49 percent of the average annual runoff volume of 7.9 bcm). The live storage volume would be 0.8 bcm or approximately 10 percent of the average annual runoff volume.

(b) Spill Facilities

The spillway discharge facilities would consist of:

1. Service outlet valves in the arch dam - with a release capacity of 920 m^3/s at maximum flood reservoir level and 770 m^3/s at minimum reservoir level.

2. A ski jump spillway located on the crest of the arch dam, with three fixed wheel gates to provide a maximum release capability of 1790 m^3.

3. An auxiliary spillway located on the crest of the north concrete gravity dam, to provide an additional 2970 m^3/s of release capability.

(c) Diversion Facilities

A single diversion tunnel long would be provided to pass the 15-year return period flood of 1630 m^3/s under free flow conditions.

Reservoir filling would commence in November and outflows from the reservoir would be controlled by operating the low level valves to pass, in each month from November to May, the minimum recorded daily average flow. During the months from June to September releases from the outlet facilities would be arbitrarily limited to 65 m^3/s which is approximately 25 percent of the long-term flow of the Iskut River at the site.

Reservoir filling curves for the Iskut canyon project for typical dry, average and wet years represented by the minimum, average and maximum years of historic record, are shown in Plate 3-3.

(d) Power Facilities

The power tunnel intake would comprise a bell mouth inlet and, 170 m downstream, a vertical concrete lined gate shaft housing one hydraulically-operated, fixed wheel gate. Approximately 850 m downstream of the gate would be a 75 m high surge shaft. The underground powerhouse would contain three Francis turbines. The power flows would be conveyed back to the river via a tailrace tunnel.

(e) Reservoir Operation

Operation of the Iskut projects was studied with the use of the SHRUMO computer program using a 35-year sequence of historical and correlated streamflow data for the period July 1940 to June 1975. The analysis indicated that for a maximum reservoir level of El. 350, a drawdown of 30 m would result in a flow utilization for power generation of 97.8 percent with a capacity factor of 50 percent.

Daily simulations of the Iskut Canyon project were made using the monthly outflows as determined by the SHRUMO program. These simulations indicate that the reservoir tended to be almost full (El. 347) for the period August to November and tended to be around minimum reservoir level (El. 317) for the period January to August.

SECTION 4.0 - HYDROLOGY

4.1 HYDROMETRIC AND CLIMATOLOGICAL DATA

(a) Streamflow Data

Plate 4-1 shows the Water Survey of Canada (WSC) streamflow data available in the Stikine-Iskut basin and in adjacent basins, and Plate 4-2 shows the locations of the stations.

As can be seen in Plate 4-1 most of the stations in the basins have continuous records dating from 1965 only, with some dating from 1972 only. The extension of the records of stations on the Stikine and Iskut rivers to the 35-year period, 1940 to 1975, required for power studies for the proposed Site Z and Tanzilla projects on the Stikine River and for the Iskut Canyon, More Creek and Forrest Kerr projects in the Iskut basin has been carried out by correlation studies described in Sections 4.2(b) and 4.3(b). This technique uses the records of stations on the Nass, Skeena and Bulkley rivers which, as seen in Plate 4-1, extend back to 1940 on a seasonal or continuous basis.

(b) Meteorological Data

Table 4-1 shows a list of meteorological stations historically operated in and near the Stikine-Iskut basin with mean temperatures and precipitations indicated where available. Plate 2-7 shows the location of the stations within the basin and has a superimposed approximate isohyetal map based on the mean precipitation values for the stations shown.

In June 1979, a network of 18 automatic climatological stations was installed by personnel from the Province of British Columbia Air Studies Branch and B.C. Hydro in the Stikine and

Iskut River basin upstream from the proposed damsites. The locations of these stations are shown on Plate 4-2, which also shows the instrumentation installed at each station, and the locations of existing AES manual stations.

Charts from these stations are collected monthly by B.C. Hydro, and after field processing, sent to the ASB Data Processing Unit in Victoria or the AES Data Processing Unit in Downsview, Ontario. Because of delays in computer processing of the data in both Victoria and Downsview, data are not presently available. Manual precipitation and temperature from the AES Stations at Bob Quinn Lake, Dease Lake and Todagin Ranch are sent to B.C. Hydro monthly from the AES Regional Data Processing Centre in Vancouver.

(c) Snow Course Data

Table 4-2 shows a list of Inventory and Engineering Branch (IEB) snow courses which have historically operated in and near the Stikine-Iskut basin with mean 1 April water equivalent (WE) values up to 1980.

In June 1979 a network of 14 snow courses was installed by IEB personnel in the Stikine and Iskut River basins; eight of these, which are located upstream from the proposed damsites, are scheduled to be sampled five times each winter on or about 1 February, 1 March, 1 April, 1 May and 1 June; six of them which are located downstream from the proposed damsites are scheduled to be sampled on 1 April only.

Table 4-2 shows a list of the 14 snow courses installed in 1979, with the recorded 1 April 1980 water equivalent values. These 1 April WE values can be compared with the 1 April 1980 data for the 10 existing snow courses and the mean 1 April data for the period up to and including 1980.

4.2 STIKINE BASIN

(a) General Hydrology

From the available streamflow records the following tabulation of annual average unit runoffs has been calculated:

Stikine River

Drainage Area above WSC gauge 08CB001 Stikine River above Grand Canyon excluding the Klappan basin	452 mm
Drainage area above WSC gauge 08CC001 Klappan River near Telegraph Creek	636 mm
Drainage area between WSC gauges 08CC001 and 08CE001 between Grand Canyon and Telegraph Creek	304 mm
Drainage area between WSC gauges 08CE001 and 08CF001 between Telegraph Creek gauge and Butterfly Creek gauge	1220 mm
Drainage area between WSC gauge 08CF001 and USGS gauge 15024800 between Butterfly Creek gauge and Wrangell gauge	2260 mm

The Stikine basin, as is apparent from the isohyetal map of Plate 2-7, lies across a region which ranges from extremely dry conditions in the north and east to extremely wet conditions in the south and west. This variation in climate is confirmed by the unit runoff values shown in the above tabulation and in the isohyets shown in Plate 2-7. It can be seen that:

1. The majority of the basin upstream from the Grand Canyon gauge is relatively dry with a unit runoff of about 450 mm, but the Klappan basin appears to be significantly wetter with a unit runoff of over 600 mm.

2. The portion of the basin between the Grand Canyon and Telegraph Creek gauges which includes the areas north of the Stikine River drained by the Tuya and Tanzilla rivers is extremely dry with a unit runoff of about 300 mm, similar to that of the Liard basin.

3. The partially glaciated portion of the basin between the Telegraph Creek and Butterfly Creek gauges which includes the areas north and south of the Stikine River drained by Mess and Yehiniko creeks and Chutine River, is intermediate between a dry and wet region with a unit runoff of about 1200 mm.

4. The portion of the basin between the Butterfly Creek gauge and the USGS gauge near Wrangell which includes the areas east and west of the Stikine River drained by such highly glacial tributaries as the Scud, Porcupine and Iskut rivers is extremely wet with a unit runoff of over 2200 mm.

(b) Streamflow Data Extension

As discussed in Section 4.2(a), the Stikine basin upstream from the Grand Canyon which would constitute the drainage area supplying runoff to the proposed Site Z and Tanzilla projects, exhibits the relatively dry climate characteristic of the elevated plateau region forming the headwaters of the Stikine, Skeena and Finlay rivers.

For a preliminary evaluation of the power potential of the proposed projects, monthly streamflow values were required for a 40-year period (1928-1968). As gauge No. 08CE001 - Stikine River at Telegraph Creek has records from 1953 and continuous records from 1965 only, it was necessary to extend the monthly streamflows at gauge No. 08CE001 by correlation with the records of the Skeena River at Usk, which as seen in Plate 4-1 has continuous records extending back to 1939 and seasonal records back to 1935. Missing periods of record were estimated from a correlation with the Fraser River at Hope.

The regression equations used for the correlation studies were of a non-linear form $y = ax^b$ and since the monthly streamflows at gauge No. 08CE001 showed the highest correlation coefficient with respect to those for the Skeena at Usk, this regression equation was used to generate 49 years of monthly flows for the Stikine. These 49 years of monthly flows for the Stikine at Telegraph Creek were then used to obtain monthly flows for gauge No. 08CB001 - Stikine above Grand Canyon. These monthly flows at Site Z and Tanzilla damsites were obtained by applying direct ratios of the drainage areas at the damsites and at gauge No. 08CB001. The monthly flows as computed from the regression equations were further adjusted to give a month by month distribution of streamflows for the period 1928 to 1954 which followed closely the characteristic pattern of flows for the Stikine River.

Tabulated monthly values of streamflow for the two damsites on the Stikine River computed by the regression equations appear in the "Stikine Development, Project Overview - Hydrology", January 1978.

Table 4-4 shows the areas used for flow generation, and the derived mean annual flows for the total period 1928 to 1976, and for the shorter period 1940 to 1975 used in the SHRUMO studies as computed from the Overview Study tabulations.

Table 4-5 shows the computed monthly mean discharge for the Site Z and Tanzilla damsites as estimated from the correlated and recorded monthly mean discharges at WSC gauge No. 08CB001, also computed from the Overview Study tabulations.

4.2 STIKINE BASIN - (Cont'd)

(c) Flow Regime Natural Conditions

All streamflow records from WSC and USGS gauges on the Stikine River and its tributaries shown on Plate 4-1 were recorded on magnetic tape. For this hydrologic study, the records for six of the stations were processed by the HYSUM Computer Program which estimates daily flow probabilities for each day of the year for the period of record and tabulates for each day the maximum, mean, and minimum flows, and the 0.75, 0.50 and 0.25 exceedance flows. The program also computes flow duration tables which tabulate the percentage of time over which flows of any specified magnitude may be expected.

Daily flow probabilities (Plate 4-3) are shown as plots of the maximum and minimum daily flows and the 25 percent, 50 percent and 75 percent exceedance flows for every day of the period of record for the above six gauges; Plate 4-6 contains flow-duration plots for the gauges.

The annual cyclical pattern for daily flows in the Stikine basins can be seen from the daily flow probability curves (Plate 4-3). Comparison of the 50 percent exceedance lines for the six stations illustrates that the annual cyclical pattern remains fairly constant throughout the basin. Flows tend to be very low during the winter period December through April, rising steadily after break-up through to mid-June, staying high until mid-August and then decreasing steadily until near the end of December.

Rare event flows, droughts and floods, show marked difference for the different hydrologic regions of the basin. In the upstream portion of the basin the major peak floods are caused by spring snowmelt. In the downstream portion of the basin, major runoff peaks are the result of rainfall and combined rainfall snowmelt events in the fall. These fall peaks can be seen in the October record for maximum daily flows at gauge No. 08CF001 Stikine River above Butterfly Creek (Plate 4-3) whereas these peaks do not appear in the maximum daily flows at the gauge Stikine River above Grand Canyon.

Floods on the Stikine, as described above, are highly dependent upon the hydrologic region. The two types of floods that occur (i.e. the spring-summer snowmelt and fall rainfall floods) can be statistically analysed jointly or independently. Plots of flood frequency for spring-summer floods, fall floods and annual floods are shown on Plate 4-7. The annual flood frequency curve at a 15-year return period was used to establish the diversion capacity needed at the damsites.

(d) Flow Regime - Regulated Conditions

The turbines in the powerhouse at Site Z are designed to utilize the mean annual flow of the Stikine River at Site Z. This would require the utilization of a maximum of 45 m of reservoir storage and the spilling of some flows during the spring and summer freshets. The turbines in the Tanzilla powerhouse are designed to utilize the mean annual flow of the Stikine River at the site. The regulated outflow of Site Z would pass through the turbines at Tanzilla and the spilled freshet inflows from Site Z would be spilled through the Tanzilla with little attenuation in the reservoir.

The operation of the Stikine Site Z and Tanzilla powerplants in the B.C. Hydro system has been simulated by the use of the SHRUMO computer program for the years 1940 to 1975. These power studies estimate only monthly average turbine flows, reservoir levels and spills. The simulated effects of the operation of the proposed Site Z and Tanzilla projects on the downstream monthly flow regimes are shown in Plate 4-4.

In general, the project would increase the winter flows (November-April) by a factor of four or five and would decrease the summer (May-July) flows by one-half immediately downstream of the reservoir. Plate 4-5 shows the corresponding effect on water levels, which indicates an increase in winter levels at the Telegraph Creek gauge of 1-1.5 m and a decrease in summer levels of similar values.

Environmental studies are being carried out to evaluate the effect of regulation of the Stikine River on the migration and spawning of anadromous fish in the lower Stikine River. These studies require the evaluation of daily regulated flows at the WSC gauge locations at Grand Canyon, Telegraph Creek, and above Butterfly Creek, and the USGS gauge near Wrangell.

The evaluation and presentation of daily regulated flows at the above locations has been performed by the use of a linked series of computer programs.

1. A program which uses the monthly turbine flows and reservoir levels computed for the years of record for the above gauges, and routes the daily average flows through Stikine Site Z reservoir from 1 May in each year to determine the required daily spills. For the years of record (1967 to 1977 for Grand Canyon and Telegraph Creek, 1972 to 1977 for Butterfly Creek, and 1977 only for Wrangell), spilling was required in 1967, 1970, 1972, 1973, 1974, 1976 and 1977. Daily outflows from Tanzilla are assumed to be equal to the monthly average turbine flows augmented by the daily computed spills.

2. A program which adds to the computed daily outflows (combined spill and turbine flows) from Tanzilla, the daily differential flows between Stikine at Grand Canyon and Stikine at Telegraph Creek for the period of record, produces the daily

regulated flows of the Stikine River at Telegraph Creek. The daily differential flow represents the inflows from the major tributaries, such as Tanzilla, Klastline, Tuya and Tahltan.

This program was used to produce the daily regulated flows for the Stikine River above Butterfly Creek for 1972 to 1977 by adding to the daily regulated flows at Telegraph Creek the daily differential flows between Telegraph Creek and Butterfly Creek - which represent the daily inflows from the tributaries, Mess and Yehiniko creeks and Chutine River.

The program also computed the daily regulated flows for the Stikine River near Wrangell for 1977, by adding to the daily regulated flows above Butterfly Creek the daily differential flows between Butterfly Creek and Wrangell, which represent the daily inflows from the tributaries, Scud, Porcupine, and regulated Iskut rivers.

3. The HYSUM program operates on the daily regulated flows for the periods of record for each location to estimate the maximum, minimum and mean daily flows, and daily flows at exceedance probabilities of 25 percent, 50 percent and 75 percent and also computes a flow duration curve based on daily regulated flows.

   HYSUM plots of computed regulated flows are shown in Plate 4-3 and flow duration plots are shown in Plate 4-6.

   Comparison of the HYSUM plots for unregulated conditions with those for regulated conditions on Plate 4-3 show the following: (Note that these plots may not be to the same scale.)

a. In the winter - November to April - regulated flows correspond to the turbine flows and would, therefore, range from about 250 m^3/s to 350 m^3/s, which is four to five times the unregulated winter flows.

b. During the spring months of May, June and early July, when the Stikine River reservoirs would be filling, regulated flows would again correspond to the turbine flows (225 m^3/s to 350 m^3/s), as compared with unregulated flows of up to 2200 m^3/s.

At Telegraph Creek, flows in those months would range from 100 m^3/s to 1350 m^3/s as compared with unregulated flows ranging from 100 m^3/s to 3250 m^3/s.

At Butterfly Creek, flows in these months would range from 100 m^3/s to 2100 m^3/s as compared with unregulated flows of between 100 m^3/s and 4000 m^3/s.

c. During the months of late July, August, September and October, when the Stikine River reservoirs would be generally filled, regulated flows would be on average only slightly smaller than unregulated flows at all gauge sites. The range during these months at Telegraph Creek would be from 100 m^3/s to 1400 m^3/s under natural conditions and from 300 m^3/s to 1000 m^3/s under regulated conditions.

The effects of flow regulation on the Stikine River at the lower Stikine River test reach has been evaluated by the following procedure:

4.2 STIKINE BASIN - (Cont'd)

- From the flow duration curve for the Stikine River above Butterfly Creek for unregulated conditions and stage discharge curves for cross sections LS1 to LS5 (Plate 5-7) drawn from concurrent stage and discharge readings at the sections obtained during the 1979 field season, water levels at each section corresponding to flows at 0.2, 0.5, 1.0, 2.0, 5.0, 10.0, 20.0, 30.0, 40.0 and 50.0 percent exceedance probabilities have been plotted on the cross sections. These plots indicate the general levels of submergence in the various channels of the Stikine River at the test reach for unregulated flows ranging from approximately 320 m^3/s to approximately 3600 m^3/s.

- From the flow duration curve for the Stikine River above Butterfly Creek for regulated conditions shown in Plate 4-6 and stage discharge curves for cross sections LS1 to LS5 water levels at each section corresponding to regulated flows have also been plotted on the cross sections (Plate 5-7). These plots indicate the general levels of submergence in the various channels of the Stikine River at the test reach for regulated flows ranging from 50 percent exceedance (approximately 450 m^3/s) to 0.2 percent (approximately 3400 m^3/s).

The effect of regulation of flows at the test reach would be to reduce the variation in stage by a factor of about 2, to reduce the magnitude of peak flows from 4000 m^3/s to 2000 m^3/s and to increase the magnitude of the minimum (winter) flows from about 85 m^3/s to 450 m^3/s.

The effect of the reduction in peak flows would cause a number of the smaller and shallower side channels to become silted up and therefore possibly causing the river to restrict itself to one or two main channels.

(e) Probable Maximum Flood and Spillway Design Discharge

(i) General

The Probable Maximum Flood (PMF) estimate for Site Z on the Stikine River was obtained using computer modelling of the basin. The flow simulation model used was the UBC Watershed Model.

The model used meteorological data, physical drainage basin data, and several calibration parameters as input, and produced estimates of streamflow as output. The physical basin data, such as area elevation relationships, were measured from contour maps. Calibration parameters were obtained through repeated attempts at reconstituting historical flows, using historical meteorological data. For the PMF estimates, only the meteorological data was modified to represent the atmospheric conditions which would produce the maximum probable flood.

The significant components of these critical atmospheric conditions are the maximum snow accumulation, the critical temperature sequence and the Probable Maximum Precipitation (PMP). Estimates of these components were made by W.D. Hogg of the Atmospheric Environmental Services (AES) of Environment Canada and are summarized in his report to B.C. Hydro entitled, Critical Meteorological Conditions for Maximum Inflow, Stikine River, B.C. (1980).

(ii) Calibration of the Model

At present, the only stream gauging stations on the upper Stikine system are the Stikine River above Grand Canyon and the Klappan River near Telegraph Creek. The streamflows at Site Z were represented by the Stikine River above Grand Canyon station, which has a drainage basin comprising about 97 percent of the Site Z basin. The flows at the Stikine above Grand Canyon gauge were modelled as the sum of flows from two separate basins, the Klappan, and the Stikine minus the Klappan. This approach was taken because the Klappan River drains a significantly wetter basin than does the upper Stikine, as indicated in the table below:

Basin	Area (km^2)	Mean Flow (m^3/s)	Unit Runoff (mm)
Klappan River	3 550	58.4	636
Stikine above Grand Canyon minus Klappan	15 250	180	452

The following meteorological stations were considered for use in the modelling to represent the atmospheric conditions over the upper Stikine and Klappan basins:

Station	Period of Record
Dease Lake	September 1944 - Present
Ware	October 1966 - Present (Many short gaps)
Todagin Ranch	August 1973 - Present
Kinaskan Lake	October 1966 - December 1970
McBride River	April 1975 - April 1978

4.2 STIKINE BASIN - (Cont'd)

Other stations, such as Hyland Post, were not considered useful because their periods of record were too short. Of the above stations, only one, McBride River, is located inside the boundaries of the upper Stikine basin, and its period of record (3 years) is the shortest in the list. Kinaskan Lake data was not used because of its proximity to Todagin Ranch, and because calibration of streamflow from 1966 to 1970 would exclude McBride River, the only station inside the basin.

Meteorological data from several stations were used in trial runs during the calibration procedure. The following table summarizes the different stations used for each set of streamflows.

Streamflow	Meteorological Stations
Klappan	Todagin Ranch McBride River Dease Lake
Stikine minus Klappan	McBride River Ware

Correlations of daily maximum temperature, minimum temperature and precipitation was carried out between Dease Lake, McBride River, Ware and Todagin Ranch for concurrent data. The following table shows the correlation coefficients obtained.

Station Pair	Maximum Temperature	Minimum Temperature	Precipitation
Dease Lake Todagin Lake	.99	.97	.46
Dease Lake McBride River	.99	.97	.56

4.2 STIKINE BASIN - (Cont'd)

Station Pair	Maximum Temperature	Minimum Temperature	Precipitation
Todagin Ranch McBride River	.99	.98	.66
Ware McBride River	.99	.97	.54

These correlations indicate that precipitation at Dease Lake follows a pattern more similar to McBride River than to Todagin Ranch. Also, a similarity exists between the patterns at Todagin Ranch and McBride River for precipitation data. This information was used for selecting stations to fill in missing data at McBride River and at Todagin Ranch.

(iii) Calibration Results

Series of computer simulations were made until successive runs showed little or no improvement in reconstituting historical streamflows. At this stage, adjustment of any of the calibration parameters usually resulted in changes in the simulated streamflows which would improve one part of the hydrograph while worsening another part. Only historical streamflows for the 3 years when McBride River meteorological data was available (1975 to 1977) were used in the calibration.

The following table shows some of the statistical results.

	Annual Volume (% of recorded)			Overall Model (Efficiency (%))		
River Basin	1975	1976	1977	1975	1976	1977
Klappan	99.7	96.6	103.2	99.2	99.2	99.2
Stikine minus Klappan	103.4	97.0	100.1	97.6	98.2	98.8

Plate 4-8 shows the recorded hydrographs and the simulated hydrographs for May to August 1976 for the two basins. These calibrations were adopted for the PMF simulations.

A. Maximum Snow Accumulation

For this study, the maximum snow accumulation was determined using the Dease Lake station only, because it is the only long-term, reliable meteorological station close to the Stikine basin. Maximized snow values at Dease Lake were then related to the key stations used in the model, and factors obtained in calibration of the model were used to relate the key station maximum snow values to the low elevation basin snow. A final adjustment was derived from snow course data, and from simulated snowpacks in the model.

In the AES Report, two approaches were used to estimate the maximum snow accumulation; the partial season method and a frequency analysis of snow course data. The partial season method entails the addition of maximum precipitation values for a given duration, taken from the entire period of record, to form a composite snow accumulation season. A duration of 4 days was chosen for this case. This method is quite sensitive to the period of record. The value of maximum snow accumulation obtained by this method was reduced by a factor of 1.6.

The AES frequency analysis used cube root normal distribution and ranked snow course data for

4.2 STIKINE BASIN - (Cont'd)

1 April where at least 10 years of record existed. The 1 in 10 000-year snow accumulation value was selected from the extrapolation of the frequency curve.

The following table summarizes the snow accumulation values obtained.

Method	Maximized Snow Accumulation at Dease Lake (mm of water equivalent)
Partial Season - 4-day duration	738
1 in 10 000-year snow course	595

McBride River maximized snow accumulation values were estimated by relating Dease Lake and McBride River October to April precipitation totals for the 3 years for which concurrent data exists. The resulting ratio of McBride River to Dease Lake winter precipitation was 1.345 to 1. During the calibration of the model, it was found necessary to multiply the snow accumulation at McBride River by a factor of .85 to represent the average low elevation snow over the Stikine minus Klappan basin. Combining the two factors, an overall factor of 1.14 is obtained, which relates the Dease Lake point snow accumulation to the average low elevation basin-wide snow accumulation for the Stikine minus Klappan basin.

The same procedure was carried out for the Klappan River basin. The ratio of Dease Lake to Todagin Ranch, October to April, precipitation was 1.128 to 1 for the common period of record. The factor found by calibration relating Todagin Ranch snow to average low elevation basin-wide snow was 1.7. Combination of these factors yields an overall factor of 1.92. This high value is supported by the observation that, as mentioned in Section 4.2(a) of this report, the unit runoff from the Klappan basin is higher than the unit runoff for the upper Stikine basin. This would indicate that the two stations represent two distinct climatic regions: Todagin Ranch showing a Pacific influence and Dease Lake exhibiting a continental climate.

The variation of this snowpack with elevation was estimated using the UBC model results for 1976 and 1977, 2 years for which the model accumulated the snow, and snow data from snow courses near the basins. A linear variation with elevation was assumed for the maximized snow values and was applied equally to the two basins. The following table compares the two sets of snowpacks used to derive the two PMF estimates:

		Snow Water Equivalent (mm)		
Source of Maximum Snow Estimate	Basin	El. 2500-3000 (ft)	El. 5000-5500 (ft)	El. 7500-8000 (ft)
Snow estimate (595 mm at Dease Lake)	Klappan	1135	1325	1516
	Stikine minus Klappan	673	864	1054

4.2 STIKINE BASIN - (Cont'd)

B. Critical Temperature Sequence

The critical temperature sequence was obtained from AES's Maximum Temperature Series graph for Dease Lake. A sequence was drawn on the graph which did not exceed any limits for the durations shown. By trial and error, sequence was found which roughly timed the peak runoff from snowmelt with the peak temperature of the sequence. This sequence began from average temperatures of 15 May and climbed steadily to a maximum of 32°C on 5 June, then dropped sharply to 16°C on 7 June, the first day of the PMP storm.

C. Probable Maximum Precipitation

Three estimates of the PMP were made by AES using three different analytic techniques. They are tabulated below:

	Precipitation (mm)			
Method	1 day	2-day	3-day	4-day
Moisture Maximization	86	122	126	128
Orographic Precipitation Model	106	160	167	175
Statistical Analysis (Hershfield)	92	114	141	149

A very brief review of the PMP methods was carried out. The moisture maximization method (individual storm analysis) is likely to give estimates on the low side. The orographic precipitation model may not be realistic in a case such as this when several mountain barriers must be crossed to reach the basin from the Pacific Ocean. AES points out that heavy summer storms are usually caused by a stationary "cold low" situated over the basin. The statistical approach is probably the weakest of the three approaches but it does yield results which are close to the average for the other two methods. The PMP obtained from the statistical approach was chosen. The 4-day maximum precipitation was broken down into the following sequence of 1 day rainfalls: 27, 22, 92, and 8 mm.

(v) Probable Maximum Flood Estimates

To evaluate the PMF for the Stikine Site Z reservoir, the calibrated UBC watershed model was supplied with 1975 to 1977 historical data to 1 May 1977. Selected maximized snowpacks for the sub-basins were assumed to exist on 1 May and from 15 May to 5 June the basin temperatures were assumed to increase from average values to historical maximum values, which constituted the critical temperature sequence. A PMP rainstorm was assumed to occur 7 June to 10 June. The resulting PMF hydrograph is shown on Plate 4-9. The total May to June volume is 15.8 bcm with a peak inflow of 9175 m^3/s on 11 June.

(vi) Spillway Design Discharge

The Probable Maximum Flood inflows must be routed through the reservoir so that the spillway design discharge can be established. The following assumptions were made for this routing at Site Z and the Tanzilla Site.

A. Site Z Project

1. Snow survey and precipitation station records would give an indication of critically large

snow accumulation by 1 February and would permit the drawdown of Site Z reservoir to the minimum permissible level of El. 749 by 15 May. With normal operation of generating facilities this reservoir would usually be drawn down close to its minimum operating level prior to every snowmelt flood.

2. After 15 May, the service outlet valves in the dam would be fully opened and would remain open throughout the duration of the PMF; however, the turbines are assumed to be shut down.

3. The auxiliary spillway would be fully open by 7 June and would remain open for the duration of the PMF.

As shown on Plate 4-9, with a peak PMF inflow of 9175 m^3/s and reservoir routing as described above, the peak outflow and consequently the spillway design discharge would be 7645 m^3/s with maximum reservoir level El. 797.

B. Tanzilla Project

The comparatively small Tanzilla reservoir would be operated on a run-of-river basis with virtually no drawdown. Consequently, the spillway and outlet valves at the Tanzilla project would be required to pass the spillway design discharge from the Site Z project of 7645 m^3/s.

4.3 ISKUT BASIN

(a) General Hydrology

From the streamflow records shown on Plate 4-1 the following tabulation of annual average unit runoffs has been calculated.

Iskut River

Drainage area above WSC gauge 08CG003 Iskut River at outlet of Kinaskan Lake	410 mm
Drainage area between WSC gauges 08CG003 and 08CG004 between Kinaskan Lake gauge and Snippaker Creek gauge excluding More and Forrest Kerr basins	1280 mm
Drainage area between WSC gauges 08CG004 and 08CG001 between Snippaker Creek gauge and Johnson River gauge	2480 mm
Drainage area above WSC gauge 08CG005 More Creek near the mouth	1870 mm
Drainage area above WSC gauge 08CG006 Forrest Kerr Creek above 460 m contour	2230 mm

As is apparent from the isohyetal map of Plate 2-7, the Iskut basin is similar to the Stikine basin as it lies across a region which ranges from extremely dry conditions in the north and east to extremely wet conditions in the south and west. This variation in the climate is confirmed by the unit runoff values shown in the above table. From these tables it is seen that:

1. The portion of the basin upstream from the outlet of Kinaskan Lake with a unit runoff of about 400 mm similar to that of the upper Stikine basin.

2. The portion of the basin between Kinaskan Lake and the Snippaker Creek gauge, which includes areas east and west of the Iskut River drained by the partly glaciated Burrage Creek

and Ningunsaw River, is intermediate between a dry and wet region with a unit runoff of less than 1300 mm. Heavily glaciated More and Forrest Kerr basins are extremely wet with unit runoffs of about 1900 mm and 2200 mm respectively.

3. The portion of the basin between the Snippaker Creek gauge and the Johnson River gauge which includes heavily glaciated area north and south of the Iskut River drained by Verrett, Twin, Craig, Hoodoo and Johnson rivers is extremely wet with a unit runoff of almost 2500 mm.

(b) Streamflow Data Extension

The More Creek reservoir would receive runoff from More and Forrest Kerr Creek, both of which have high unit runoffs (1870 mm and 2230 mm respectively). The Iskut Canyon project takes runoff from the dry continental area above Kinaskan Lake, the moderately dry area from Kinaskan Lake to More Creek and the regulated runoff from the More Creek project.

As explained in Section 4.2(b), the preliminary power studies were based on the 40-year period (1928-1968). Using the procedures explained in Section 4.2(b), a non-linear regression equation of the form $y = ax^b$ was used to reconstitute streamflows. Tabulated monthly values of streamflow for the two damsites in the Iskut basin computed by the regression equations appear in the Overview Study. Table 4-4 shows the areas used for flow generation and the derived mean annual flow for the period 1928-1968 and for the shorter period 1940-1975 used in the SHRUMO studies as computed in "Iskut Development Project Overview - Hydrology" January 1978.

Table 4-5 shows the computed monthly mean discharges for the Iskut Canyon and More Creek (post-diversion) as used in the power studies, also computed from the Overiew Study tabulations.

(c) Flow Regime Natural Conditions

All streamflow records from WSC gauges on the Iskut River and its tributaries, shown on Plate 4-1, have been recorded on magnetic tape. For this hydrologic study, daily flow probabilities have been estimated for each day of the year. These probabilities are plotted on Plate 4-3 for four stations in the basin. Flow-duration curves for the stations are plotted on Plate 4-6.

The annual cyclical pattern for daily flows in the Iskut basin can be seen from the daily flow probabilities (Plate 4-3). Comparison of the 50 percent exceedance lines on the three stations shown illustrates that the annual cyclical pattern is similar. The only difference being that the flows in Forrest Kerr Creek have a more distinct mid-summer peak. This is due to the large proportion of Forrest Kerr Creek which is glacier-fed and so responds to the high summer temperatures.

Rare event flows, floods and droughts are similar to those in the lower Stikine basin as described in Section 4.2(c). The major floods are the result of fall (October and November) rainfall and combined snowmelt/rainfall events. These peaks can be seen on the daily flow probabilities for the three stations. Minor floods also are caused by the annual snowmelt (freshets) which appear in July and August. These flows are as high as the fall events on Forrest Kerr. Droughts at three stations can be examined by looking at the minimum flow lines on the daily flow probabilities. The droughts on Forrest Kerr Creek would appear to be more severe, which is probably a result of a smaller watershed and consequently lower base flow.

Floods on the Iskut can be divided into the spring-summer snowmelt events and the fall events. These events can be statistically analysed jointly or independently. Plots of flood frequency for spring-summer, fall and annual floods are shown on Plate 4-7. The annual flood frequency curve at a 15-year return period was used to establish the diversion capacity needed at the damsite for each project.

(d) Flow Regime-regulated Conditions

The reservoir for the More Creek project has a live storage volume of 1.3 bcm. This volume regulates the More Creek flows and the additional flow from the Forrest Kerr diversion. This regulation will serve to capture the spring-summer freshet and release the water through the winter. Since major fall floods, although large, are not predictable, the reservoir must be filled for winter earlier in the year, and consequently, the fall floods must be spilled.

The reservoir for the Iskut Canyon project has a live storage volume of .8 bcm which is used to regulate the flows which are not regulated by the More Creek project. The Iskut Canyon reservoir is operated in the same manner as the More Creek project which again necessitates the spilling of the fall flood flows.

The operation of the More Creek and Iskut Canyon projects has been simulated with the use of the SHRUMO computer program for the years 1940-1975. These power studies estimate only monthly average turbine flows, reservoir levels and spills. The effects of the operation of the proposed More Creek and Iskut Canyon projects on the downstream monthly flow regimes are shown on Plate 4-4. In general, the winter (November-April) flows would be increased and the flows would be reduced in the summer (May-July). At the gauge near Snippaker Creek, the flows would increase in the winter by a factor of 1.5 to 4.5 which would correspond to a change in water levels (Plate 4-5) of up to 1 m.

During the summer period, the flows would be decreased by a factor of up to 0.5 which would correspond to a reduction in water levels of up to 1 m.

Environmental studies are being carried out to evaluate the effect of regulating the Iskut River (including the regulation of More and Forrest Kerr creeks) on the migration and spawning of anadromous fish in lower Iskut River. These studies require the evaluation of daily regulated flows for the Iskut River at WSC gauge locations above Snippaker Creek and below Johnson River.

The evaluation of daily regulated flows at the above locations has been performed by the use of a linked series of computer programs:

1. A program which routes daily average More Creek and Forrest Kerr Creek flows for the period of record (1972-78) through More Creek reservoir using the monthly average turbine flows from the SHRUMO program as outflows and computing the required daily average spills required. For those years, no spilling was required and so the daily outflows are the turbine flows only. During the winter months, More Creek reservoir reaches the permissible minimum level and the power units are assumed to operate on inflow only.

2. A program which adds to the daily outflows from More Creek reservoir the daily differential flows - Iskut River above Snippaker Creek less the daily sums of More Creek near the mouth and Forrest Kerr Creek at the 460 m contour. These differential flows represent the unregulated flows of the upper Iskut River and when augmented by the outflows from More Creek reservoir represent the inflows to Iskut Canyon reservoir for the period of records (1972-78).

3. A program which routes daily average inflows to Iskut Canyon reservoirs for the period of record (1972-78) through the reservoir using the monthly average turbine flows from the SHRUMO program as outflows, and computing the required daily average spills to keep the reservoir from exceeding the maximum permissible level. For those years, spilling was required generally in July and August and occasionally in September and October, and in most winters, Iskut Canyon reservoir reaches the minimum permissible level and the power units.are assumed to operate on inflow only.

4. A program which adds to the computed daily outflows from Iskut Canyon project - consisting of the turbine flows augmented by the daily computed spills - the daily differential flows between Iskut River above Snippaker Creek and Iskut River below Johnson River for the period of record 1972-78 which represent the daily inflows from the tributaries - Snippaker, Craig, Hoodoo and Johnson. The outflows from Iskut Canyon project represent the daily regulated flows of the Iskut River above Snippaker Creek for the period of record 1972-78 and the sum of these outflows and the differential flows represent the daily regulated flows of the Iskut River below Johnson River for 1972-78.

5. A program which sums the daily regulated flows of the Stikine River above Butterfly Creek and the daily regulated flows of the Iskut River below Johnson River for 1972-78; and adds to the sum the daily inflows from the portion of the lower Stikine basin downstream from Butterfly Creek, computed as 2.5 times the daily difference in inflow between the gauges on the Iskut River above Snippaker Creek and below Johnson River for the period 1972-78 (representing the daily unregulated inflows of the tributaries - Scud, Porcupine and Katete rivers).

This sum represents the daily regulated flows of the Stikine River near Wrangell for 1972.

6. The HYSUM program which operates on the daily regulated flows for the periods of record for each location estimate the maximum and minimum daily flows and daily flows at exceedance probabilities of 25 percent, 50 percent and 75 percent, and also computes a flow duration curve based on the daily regulated flows. Plots of the HYSUM computed regulated flows are shown on Plate 4-3 and duration plots on Plate 4-6.

Comparison of the HYSUM plots for unregulated and regulated conditions on the Iskut and on the Stikine below the Iskut confluence, show the following:

1. In the winter months - November to April - regulated flows from Iskut Canyon project which constitute the regulated flows at gauge 08CG004 - Iskut River above Snippaker Creek - correspond to the turbine flows. Because of the limited storage capacities of More Creek and Iskut Canyon reservoirs in most years, winter generation would appear to decrease as the levels of the reservoirs approach the minimum permissible level; and, therefore, by February and throughout March and April, outflows from Iskut Canyon reservoir would approach the values of the natural flows of the Iskut River above Snippaker Creek. Flows in the Iskut River below Johnson River during the winter months could be as high as 280 m^3/s during January because of the high outflows from Iskut Canyon reservoir (compared with natural mean annual flows in January of 60 m^3/s) but in March and April, average flows at this gauge would approach the natural flows.

4.3 ISKUT BASIN - (Cont'd)

In the winter months, flows of the Stikine River near Wrangell, after regulation of the Stikine and Iskut rivers would range between 450 m^3/s and 850 m^3/s in January, 400 m^3/s and 650 m^3/s in February and 370 m^3/s and 480 m^3/s in March, compared with natural flows in those months which range from 200 m^3/s to 900 m^3/s. In April, regulated flows of the Stikine River near Wrangell would increase to between 400 m^3/s and 1200 m^3/s mainly because of increased tributary flows.

2. In the months of May, June and early July, regulated flows at the Stikine River near Wrangell would be considerably reduced from the natural range of flows (400 m^3/s to 7300 m^3/s). Regulated flows would range from 560 m^3/s to 2500 m^3/s in May, 1700 m^3/s to 4000 m^3/s in June and 1700 m^3/s to 6400 m^3/s in early July.

3. By mid-July, the reservoirs would usually be filled and outflows in late July, August and September would be only slightly reduced so that average regulated flows in the Stikine River near Wrangell would be just slightly lower than the average natural flows.

4. In October and November, the reservoirs would be close to full, so that the sudden high peak flood flows (characteristic of the lower Iskut and lower Stikine basins) would be discharged through Iskut Canyon spillway with only a slight attenuation. This effect can also be noticed on Flood Frequency Plots (Plate 5-11) where regulation produces very little change in the magnitude of fall floods. The small attenuation that does occur is from the surcharging of the reservoir.

(e) Probable Maximum Flood and Spillway Design Discharge

(i) Probable Maximum Flood

Due to a complete lack of meteorological data in the Iskut basin which could be used to calibrate a basin model, it was necessary to repeat the approximate estimate of PMF peaks and volumes made for the overview study.

These preliminary PMF estimates were based on reconstitution of the maximum recorded flood of October 1961 which was measured only at the gauge Iskut River below Johnson River (WSC No. 08CG001). Estimation of corresponding flood peaks and hydrograph shapes at other stations in the basin were made using the second highest recorded flood of October 1974 as a guide. The magnitude of the 1961 and 1974 flood peaks can be seen on the daily flow probabilities for Iskut River below Johnson River (Plate 4-3). Arbitrarily the October 1961 flood hydrographs were scaled up by a factor of 2 for the Iskut Canyon and More Creek projects. The factor 2 appears to be the typical ratio for escalating maximum recorded flood peaks up to PMF peaks for projects in British Columbia.

The following table compares the 1961, 1974 and Probable Maximum Floods for the three project sites:

Site	Flood of 5-14 October 1974 Volume ($m^3 \times 10^6$)	Flood of 5-14 October 1974 Peak (m^3/s)	Estimated October 1961 Flood Peak (m^3/s)	PMF Peak (m^3/s)
Iskut Canyon	732	2521	3824	7648
More Creek	127	603	1079	2153
Forrest Kerr Creek	82	191	263	523

(ii) Spillway Design Discharge (SDD)

The spillway design discharge for the More Creek project was established by routing the Probable Maximum Flood through the reservoir using the following assumptions:

1. The Probable Maximum Flood would occur as a result of an autumn storm. Such a storm would contribute large volumes of rain and snowmelt inflow into the More Creek reservoir with such rapidity that only a minor amount of drawdown would be possible.

2. On October 1, with the reservoir at maximum normal reservoir level (El. 528) the service outlet valves and the auxiliary spillway would be fully opened and would remain open for the duration of the PMF. The turbine however is assumed to be shut down.

   The PMF for Forrest Kerr Creek is added to the PMF for More Creek with a resultant peak of 2676 m^3/s and the reservoir routing as

4.3 ISKUT BASIN - (Cont'd)

described above results in a spillway design discharge of 1580 m^3/s. The shape of the hydrograph can be seen on Plate 4-9.

The spillway design discharge for the Iskut Canyon project is the result of the Probable Maximum Flood at the site, except that the More Creek and Forrest Kerr Creek contributions are assumed to be attenuated by reservoir routing in the More Creek reservoir.

The assumptions made for routing the Iskut Canyon PMF are similar to those used for the More Creek project.

1. The Iskut Canyon PMF would be the result of the same autumn storm which produced the More Creek PMF and would be coincidental in time with it. As with the More Creek project only a minor amount of drawdown would be possible.
2. On 1 October with the reservoir at maximum normal level (El. 347), the service outlet valves would be fully opened and would remain open for the duration of the PMF. The turbines however are assumed to be shut down.

Plate 4-9 shows the shape of the hydrographs for the PMF and the spillway design discharge. The peak inflow for the PMF is 6286 m^3/s and with reservoir routing as described above the resultant spillway design discharge is 5683 m^3/s.

SECTION 5.0 - SEDIMENTATION

5.1 SUSPENDED-SEDIMENT PROGRAM

In the project overview studies for the Stikine and Iskut developments prepared by the Hydrology Section for the HGPD Development Department in September 1977 and March 1978 respectively, estimates were made of the mean annual sediment concentration, in mg/L, of the Stikine and Iskut rivers and their tributaries. Estimates were also made of the mean annual sediment load in tons per square mile transported by the two rivers and their tributaries, and of the expected life of the reservoirs at Site Z on the Stikine River, and at More Creek, Forrest Kerr Creek and at Iskut Canyon on the Iskut River. These estimates were based on generalized data for Canadian rivers given by Stichling (1974).

The overview report emphasized the preliminary nature of such estimates and recommendations were made for the establishment of a suspended-sediment monitoring program in the Stikine and Iskut River basins. It was suggested that such a program be carried out for several years to determine the sediment yield from the basins, the useful life of reservoirs, degradation and aggradation of river channels, formation of deltas at the upstream ends of reservoirs, etc. It was also suggested that river regime and morphology studies of the whole length of the two rivers be carried out.

The program was carried out during the open water periods (May to November) in 1978 and 1979. The suspended-sediment concentration data obtained in this program appear as Table 5-1. A plot of the grain size distribution of the material appears as Plate 5-1. Suspended-sediment samples were taken at three Water Survey of Canada (WSC) stations in the Stikine basin and at four stations in the Iskut

5.1 SUSPENDED-SEDIMENT PROGRAM - (Cont'd)

basin at approximately 1 month intervals by B.C. Hydro and WSC personnel, using standard WSC depth integrated samples where possible and dip samples only when necessary.

The samples were analysed for concentration and particle size at the WSC Sediment Survey Laboratory.

Rating curves (discharge vs. concentration) have been plotted for each sampling site (Plate 5-2).

5.2 SUSPENDED-LOAD TRANSPORT

From the rating curves and the recorded streamflow hydrograph suspended-sediment concentration hydrographs were computed for each station for the sampling periods in 1978/79. Measured concentration values were plotted on these hydrographs, for comparison with the computed concentration values on those dates. Where necessary, corrections to the computed concentrations were made for the dates when samples were taken, and computed concentrations were varied linearly with time between observations to obtain a smooth concentration hydrograph that fits the observed data exactly and varies with the general trend of the streamflow hydrograph. Tables 5-2 and 5-3 show the yield in tonnes (dry weight) as computed on a daily basis for the years 1978 and 1979, respectively. The tables show the yield computed during the sampling period of April to September and an estimate of the annual amounts. These annual estimates are generally lower than the long-term average annual estimate (Table 5-6) due to the lower than average annual runoff in those years.

Long-term annual yields for the seven stations (three in the Stikine basin, four in the Iskut basin) were computed using suspended-sediment rating curves and flow duration curves for the WSC gauges based on the entire period of record.

5.3 TEST REACH SURVEYS

(a) General Comments

From experience with other B.C. Hydro projects and from the technical literature it was clear at the onset of the present studies that the proposed projects could have many effects on the rivers downstream. It is also known that these effects could vary greatly, depending on the morphology of affected reaches and on the magnitude of the imposed primary changes to the flow regime and in sediment supply from upstream. Since complete detailed surveys of the downstream rivers would have been exceedingly costly and time-consuming, a test reach approach was adopted. This requires the selection of relatively short "typical" reaches for each river segment with a distinct channel morphology. The test reaches were surveyed and studied in considerable detail. The resulting general predictions of future changes could be applied to the entire river segment characterized by the test reach. The assumed primary changes to the flow and sediment transport regimes would not be restricted to the expected changes at the actual test reach site. With the appropriate scaling for discharge one can even estimate changes for sites much closer to the dam or much further downstream, where the imposed primary changes might be greater or reduced due to tributary inflows.

Besides their use in estimating downstream effects, test reach surveys are also required for bed-load computations. The sediment transported in close contact with the streambed, the so-called bed-load, is very difficult to measure but can be estimated roughly from hydraulic parameters (Section 5.4). Bed-load is a major component of reservoir sedimentation and is therefore important in estimates of reservoir life (Section 5.5). In the case of the present project it was decided that bed-load estimates should at least be obtained for the Iskut River because of the relative smallness of the Iskut Canyon reservoir and for More Creek because of the expected very high transport rates.

5.3 TEST REACH SURVEYS - (Cont'd)

A typical test reach survey consists of at least five cross sections approximately evenly-spaced to intercept a variety of channel conditions (straight reaches, bends, single and multiple channels). At each cross-section, water levels are observed over as wide a range of flows as possible. In the case of braided rivers, several water levels are observed at most sections as there can be large differences across the channel zone (up to 2 m in the case of the lower Iskut reach). From the cross section data, longitudinal profiles can also be drawn up. The grain-size distribution of the bed materials is defined on the basis of grid or sieve samples. No discharge or velocity data have been obtained so far, but a mean velocity is computed on the basis of estimated discharge and cross-sectional area. All survey data are coded and processed by a computer program that evaluates a wide range of standard hydraulic parameters for each section and for all reaches between sections. Overall test reach averages are also computed.

(b) Stikine River

There are four major types of channel morphologies along the Stikine River downstream of the proposed projects (Section 2.4):

1. The first is the deeply incised bed-rock canyon from the Tanzilla damsite to the vicinity of Telegraph Creek. Only minor morphological changes can occur along such a reach and they are reasonably predictable on the basis of map and air photo information so that there did not appear to be any need for field surveys.

2. The second morphologic type is the entrenched, mainly single channel reach from Telegraph Creek to the Chutine confluence. The potential for morphologic changes along this reach is

somewhat greater, but still minor. Based on B.C. Hydro's experience with regulation of the the Peace River which has a comparable morphology, the probable changes are also quite predictable. A new test reach has recently been established in this area but no data are presently available from it.

3. The 135 km split-to-braided and unstable reach between the Chutine River and the Alaska border has by far the greatest potential for morphological changes and a test reach was therefore surveyed to characterize it. In selecting the reach an attempt was made to find a site that was both typical of the entire braided reach and contained a variety of fish habitat. A preliminary environmental study by Northern Natural Resources Limited in 1979 listed a large number of reaches on the lower Stikine River where salmon had been observed to spawn. The reach finally selected starts some 7 km upstream of the Scud River confluence and is 11 km long. This reach is referred to as the "Lower Stikine River Test Reach". Cross sections and bed material size distribution curves are shown in Plates 5-7 and 5-8 respectively.

4. The last 10 km of the Stikine River in Canada are characterized by a fourth distinct type of fluvial morphology (single channel with islands to split, with a wide alluvial floodplain) which extends to the upstream end of the tidal reach in Alaska. Since most of that morphology occurs in Alaska it is being studied in conjuction with the ongoing studies of the Alaskan reach and Stikine estuary.

(c) Iskut River

The Iskut River reach between Iskut Canyon damsite and the river mouth at the Stikine confluence has three major channel morphologies. An upstream incised, canyon-like reach (15 km) is

5.3 TEST REACH SURVEYS - (Cont'd)

followed by a highly-braided glacial valley train (49 km) with a final short (10 km) single-channel reach with occasional islands similar to the lower Stikine.

As in the case of the Stikine, the lower downstream single channel reach could be subject to morphological changes, but local tributary inflows dampen changes in the primary flow and sediment supply. The reach is also partly affected by backwater from the Stikine which would complicate any attempt at predicting changes. Survey of a Stikine River test reach in Alaska would provide some of the information needed for predicting changes along the lower Iskut.

A test reach was selected along the intermediate, highly braided reach using criteria similar to those used in the case of the Stikine River. The Craig River and Hoodoo River confluences fall within the reach and two of the five cross sections cross the lower Craig River also. Although this complicates data analysis because discharge cannot be assumed constant, the reach was selected because the lower Craig River is important from a fisheries point of view. The results of this survey are shown on Plates 5-6 and 5-8. This reach is referred to as the "Lower Iskut River Test Reach."

The "Upper Iskut River Test Reach" was surveyed above the proposed Iskut Canyon reservoir, mainly for the purpose of bed-load computation. While it had also been intended to include the upstream end of the reservoir within the reach to provide a basis for future reservoir delta surveys, there have been several changes in proposed reservoir level since the reach was selected and it now falls within the reservoir. The morphology along this upper reach is single-channel with islands to split, occasionally confined, and partly entrenched. The results of the survey appear on Plates 5-5 and 5-8.

5.3 TEST REACH SURVEYS - (Cont'd)

(c) More Creek

A further test reach was surveyed along the north fork of More Creek. It covers a short, mostly single-channel segment between the canyon mouth and the highly braided channel zone of the broad main More Creek valley. As in the case of the upper Iskut reach, this survey was mainly intended to provide data for bed-load computations, but it also covers the end of the proposed reservoir and could be used as a basis for future delta growth estimates. The reach covers the channel segment for which bed-load computations appear to have the best chance of success.

5.4 BED-LOAD COMPUTATIONS

The bed-load transport rate of gravel-bed channels depend both on channel hydraulics and on upstream supply. Numerous field observations reported in the literature have demonstrated that, under conditions of slowly-rising flow, significant bed-load transport starts at a distinct flow level. Initially the material transported will be considerably finer than the prevailing bed armour and most of the bed-load will consist of coarse sand. This initial load is mainly supply-dependent and it therefore constitutes part of the wash load. As flow increases, both the transport rate and the average grain size of the transported material would increase, until, at very large flows, there would be little difference between the bed material and the bed-load. At this stage, the transport rate is essentially independent of upstream supply and it should therefore be possible to determine it from the channel hydraulics. On the falling stage after such a large flow the transport rate is generally somewhat lower than on the corresponding rising stage as the river bed is gradually winnowed of fines and the normal coarse channel armour becomes re-established. Existing computational procedures for bed-load transport are only very incomplete representations of the true process and the results should be accepted as order-of-magnitude estimates.

5.4 BED-LOAD COMPUTATIONS - (Cont'd)

Moreover, the formulas not only fail to represent the basic physical processes properly, but are also based on the assumption of two-dimensional flow, an assumption that is extensively violated by the flow conditions in all of the present test reaches. Several studies have, however, shown that it is possible to compute reasonable bed-load estimates even for river channels as irregular as some of the ones encountered here. (Hollingshead, 1971; Church, 1975).

The present computations, summaried in Table 5-7, are based on Einstein's formula (Einstein, 1950) and were executed with a program written by M. Church. The computations of cross-sectional average hydraulic parameters were adjusted manually to eliminate from consideration the flow across floodplain segments and high bar surfaces. Failure to eliminate such flows would result in a reduction of average boundary shear with increasing depth due to the rapidly increasing width, clearly an unreasonable result.

The computed results shown in Table 5-7 are very sensitive to the assumed bed material grain-size. In all cases, an average size distribution was estimated based on the fraction greater than 8 mm. Most of the transport of material finer than 8 mm is probably supply-dependent so that there would be no point in including it in the computations. Both this omission of the finer part of the bed-load and the fact that the bed material sampling program ignored the frequent areas of pure sand in most test reaches indicate that the computed bed loads are lower-bound estimates.

Table 5-7 presents the results of the bed-load transport analysis. These results are incorporated into the reservoir life calculations (Section 5.7). This table also contains the hydraulic characteristics for the 0.2 percent probable streamflow. This corresponds to the streamflow that is likely to be equalled or exceeded approximately 1 day per year. A large portion of the bed-load transport occurs under those conditions.

5.5 EFFECTS ON DOWNSTREAM RIVER REACHES

(a) General Comments

Relatively large storage reservoirs, as proposed for the Iskut and the Stikine rivers would modify the flow, sediment transport, and ice regimes along downstream river reaches. In addition to local geologic controls, these are the three main factors that determine the size and morphology of a river and it is therefore not surprising that extensive morphological changes have been observed downstream of many dams. The types of changes to be expected are known in a general, qualitative sense but for several reasons it is not normally possible to quantify the expected changes in any detail. The two main problems are (following Kellerhals, 1980):

1. Lack of theoretical, quantitative models for some of the main processes involved.

2. Impractical data requirements of some of the existing theoretical models.

Under Item 1, the major deficiency relates to the three-dimensional aspects of fluvial morphology. Existing sediment transport models can only handle two-dimensional or very simple three-dimensional flow situations, assuming channels of fixed width, essentially flat beds and known alignment. In the present situations, where wide, shallow and highly braided channels will be affected, the future channel width, cross-sectional shape and plan form are the primary unknowns and they can only be estimated on the basis of precedent and some purely empirical relations.

Item 2, the impractical data requirements, refers mainly to large variations of bed material and subsurface material sizes, and to sediment transport rates. Bed material size is often so variable that it cannot be narrowed down sufficiently for the requirements of most theoretical models. Subsurface materials become highly relevant in rivers where downstream degradation is possible. Without extensive subsurface sampling programs defining the variation in sizes accurately would be a monumental task. Bed material load is well known to be one of the main factors determining channel morphology but it is difficult and costly to measure, and, assuming it had been measured in the main stem river and its tributaries, one would be little further ahead because the relationship between flow, sediment transport and channel morphology is only known in a general, qualitative way.

(b) Iskut River

As explained in Section 4.3(d) and as illustrated by the flow probability curves on Plate 4-3 and by the flood frequency curves on Plate 4-7, the primary effects of the Iskut development on downstream flows would consist of a 20 to 40 percent reduction in the magnitude of spring and summer flood flows combined with a considerable shortening of the period of high flows, and an increase in winter flows by a factor of 1.5 to 4.5. The very large fall flood peaks would be reduced somewhat, but the larger the flood the less the effect of the two reservoirs. The Iskut Canyon reservoir would trap the entire bed load of the Iskut River and at least the sand and silt portions of the suspended-load.

Along the initial 18 km reach of incised, stable channel, morphological changes would probably be minor. The present hydraulic geometry and bed material size along that reach are unknown at present but should be known after surveys planned for 1980 are completed. The reach between the powerhouse and McLymont Creek would have its entire bed-load supply cut off and would therefore take on the appearance of a lake outlet channel. The channel morphology would stay essentially unchanged, but the channel bed would be winnowed of the finer gravels and a very stable lag armour with a D_{90} around 500 mm would develop. Depending on the amount of such coarse materials available in the streambed there could be degradation. Only the larger floods would be capable of degrading the bed significantly, and it would therefore take many years until an equilibrium is reached.

Both McLymont and Snippaker creeks are thought to contribute significant gravel loads to the Iskut River. A new equilibrium between their sediment loads and the carrying capacity of the Iskut River would have to develop gradually. The project would reduce both the carrying capacity of the Iskut River for coarse gravel by reducing the duration of high flows, and the bed-load by eliminating the supply from upstream. If the effect of reducing carrying capacity were to predominate, there could be some aggradation of the Iskut River at the confluence. With the effects of load reduction dominating, which appears more likely in view of the many highly loaded tributaries that the Iskut River receives upstream of the Iskut Canyon damsite, there would be some degradation combined with coarsening and stabilization of the bed.

Changes along the upsteam parts of the braided reach would likely be far more pronounced than those between McLymont and Snippaker creeks. However, the relations between channel morphology, the discharge regime, and sediment supply are only generally known, so that it would be pointless to try and make reliable predictions of future channel morphology. It is possible to indicate the limits of what might happen, together with a rather subjective estimate of what is most likely to happen.

At one extreme, it can be assumed that the reduction in transport capacity for sand and gravel of the Iskut River could exceed the reduction in sediment supply. Under these circumstances there would be little change as the braided reach already appears to be aggrading under natural conditions. It would simply continue to aggrade at a somewhat increased rate. At the other extreme it can be assumed the transport capacity under regulated conditions could greatly exceed supply from upstream. In that case the Iskut River would incise itself into the present braided channel zone and would develop a stable, armoured single channel. The depth of incision would depend entirely on the availability of coarse material in the present alluvial valley fill. In order to operate at its present slope of 0.00195, the channel would have to be armoured by material with a D_{90} of approximately 400 mm, which is not likely to be available. The armoured channel would probably have a width of approximately 150 m and the braided channel zone would slowly become a vegetated terrace with the former channels gradually becoming filled with fines and organics.

In order to make best possible use of available data for a "most probable" prediction, an extensive search of the technical literature was undertaken to locate sets of combined slope, discharge and bed material size data for braided channels. The results are shown on Plate 5-10 in the form of a plot of discharge (2-year flood, estimated "dominant discharge", or "bankfull" in that order of preference) against the slope of the braided channel zone, with D_{90} as a third parameter, indicated by the size of the plotted symbols. A detailed write-up of that study is under way. Two channel morphologies are distinguished, truly braided channels, such as the lower Iskut River or More Creek and split, unstable channels (sometimes called "wandering" or "anastomosing"), which is really a lesser degree of braiding and is well illustrated by the morphology of the Stikine River test reach. The plot indicates that, at a given discharge, braided and split channels on gravel beds occur over approximately a one-log cycle range of slope, with little apparent effect on grain size. This wide scatter must be due to the effect of sediment supply. Those rivers with a large sediment supply are likely to plot near the top of the range (steepest slopes) and this is confirmed by

5.5 EFFECTS ON DOWNSTREAM RIVER REACHES - (Cont'd)

the fact that many of the proglacial rivers, which usually do have large sediment supply, tend to plot near the top of the range.

On Plate 5-10, the lower Iskut River test reach plots near the lower end of the braided zone and this suggests that a significant reduction in sediment supply, which the proposed project would cause, would bring the river into the split or wandering zone by inducing a tendency to reduce its slope. The reduction in "dominant" discharge due to regulation would have the same effect by shifting the river's plotting position leftward.

The most probable morphologic change in the braided zone would therefore be a reduction in the degree of braiding combined with some entrenchment of the new, split channel zone. Downstream of the Craig and Hoodoo River confluences, changes are likely to be negligible but in the upper reaches of the braided zone one might expect a reduction in channel zone width by a factor of 2 to 4.

The new channel zone would also likely contain relatively less sand than at present since the Iskut Canyon reservoir will retain a large portion of the suspended load, 38 percent of which consists of sand.

Morphological changes along the last Iskut River reach, the 10 km of single channel with occasional islands immediately above the river mouth, would likely be minor. The changed discharge regime would have some effect on the frequency of flooding across the broad floodplain. This, in turn, might affect vegetation and possibly fish access into some of the ponds and spring-fed streams on the floodplain. Evaluation of these effects would require the determination of the water level regime at sites typical for this channel morphology, either on the lower Iskut or, preferably, on the lower Stikine.

5.5 EFFECTS ON DOWNSTREAM RIVER REACHES - (Cont'd)

(c) Stikine River

Since the Stikine River below the project is basically similar to the Iskut River with three distinct morphologies (single channel, entrenched and stable to the Chutine River, split and unstable to the Great Glacier and single channel with islands and a broad floodplain to the U.S. border), the downstream effects would be quite similar. There are, however, some important differences. Comparison of the natural and regulated flow probability plots (Plate 4-3) shows that, owing to the lack of fall rain floods on the Stikine River upstream of the Site Z dam, and to the larger storage capacity of that dam, regulation would be more effective, and the carrying capacity for coarse sediments would therefore be more severely reduced. At Telegraph Creek, the larger summer flows would be reduced by a factor of around 2.5 to 3.5, while winter flows would be increased by factors of 4 to 5. This suggests that there would be some aggradation at tributary mouths, particularly at the mouth of Mess Creek which seems to carry an unusually large gravel and cobble load.

Downstream of the Chutine River confluence the Stikine exhibits a tendency towards braiding but it is much less pronounced than on the Iskut River and does not warrant a classification as "braided". The plotting position of the lower Stikine on Plate 5-10 near the upper end of the zone for split or wandering channels suggest that there could be a considerable reduction in sediment supply or in "dominant" discharge without effecting a basic change in morphology. It therefore appears probable that the lower Stikine between the Chutine confluence and the Great Glacier would maintain its present split and unstable morphology, but there would be some reduction in channel zone width. The downstream single channel with islands reach would probably be affected similarly to the lowest Iskut reach and detailed assessment would also have to wait for further survey results.

5.6 SEDIMENTATION ASPECTS OF THE FORREST KERR CREEK DIVERSION

(a) Introduction

Forrest Kerr Creek would be diverted towards the south branch of More Creek by means of a low dam situated approximately 3 km downstream of the two snouts of Forrest Kerr glacier (Plate 3-4). The dam, with a crest at El. 570.0 would impound the flow of Forrest Kerr Creek and divert it through a partly excavated channel across the divide towards More Creek at approximately El. 562.0. No spillway or other outlet works are proposed for the diversion dam so that the diversion flows would be entirely unregulated.

(b) Potential Evolution of the Diversion

A general, qualitative description of the morphological developments that would be likely to take place along the diversion route is given here with more detailed discussion of the various phases in subsequent sections.

During an initial period following diversion, both branches of Forrest Kerr Creek would be flowing into the diversion pool and would be depositing their bed-load and the coarser fractions of their suspended-load there. The essentially sediment-free diversion flow would, depending on slope and grain size along the diversion route, erode a more or less incised diversion channel to More Creek. From the confluence with More Creek down to the new reservoir, the diversion would greatly increase natural flows in a highly-braided gravel-bed channel, without a corresponding increase in sediment load. This would be likely to lead to some morphological changes.

As the western end of the diversion pool filled with sediment, first the north fork, and eventually both forks of Forrest Kerr Creek would begin to transport coarse sediment into the diversion channel. This would lead to gradual aggradation and to the eventual formation of braided gravel bed channels from the two snouts of Forrest Kerr glacier to the More Creek reservoir. The eastern part of the diversion pool would probably maintain a connection to Forrest Kerr Creek, but it would no longer receive much sediment and might therefore persist for hundreds of years. As the area of the divide would aggrade due to the heavy gravel load of Forrest Kerr Creek, the water level in the remains of the diversion pool would also increase. As there would be little need or incentive for the operating staff of the project to inspect and monitor the diversion dam area, it might be advisable to build the diversion dam to a height that would assure continued diversion even after a new, stable Forrest Kerr Creek has developed across the divide area.

(c) Initial Phase

During the initial phase, the coarser part of the Forrest Kerr Creek sediment load would be deposited in the diversion pool and the diversion channel to the south fork of More Creek would adopt the properties of a lake outlet channel.

The dimensions of natural lake outlet channels have been investigated by Kellerhals (1967). His relation between slope S, 2-year flood discharge, Q, and bed material size, D_{90} is:

$$S = 0.12\, Q^{-0.4}\, D_{90}^{0.92} \text{ (in Imperial units)}$$

It is based on a purely empirical channel width relation, a tractive force criterion for a stable channel armour and a resistance law similar to the Manning formula. With the slope of the diversion route of 0.0265 (Plate 5-9) and the 2-year maximum diversion flow of 201 m^3/s, one obtains an armour size of 227 mm. Whether sufficient material of this size to armour an incised channel is available along the diversion route is doubtful, but the following points also need to be considered.

5.6 SEDIMENTATION ASPECTS OF THE FORREST KERR CREEK DIVERSION - (Cont'd)

1. The above equation is based on observations made along natural lake outlet channels which may have been in operation for hundreds or thousands of years and are therefore very stable (may have coarser armour than required for stable operation over a period of a few decades).

2. A gravel sample taken close to the point where the More Creek south fork emerges from its canyon has a D_{90} of 245 mm, although two samples taken somewhat further downstream have D_{90} values of 105 mm and 78 mm only.

3. Materials along the diversion route have not been sampled but the relatively flat slope suggests that the predominant fluvial deposits, at least, might be medium to fine gravel. This has been confirmed by field inspection. However, the diversion route crosses several small terminal moraines and there might be extensive till deposits containing cobbles and boulders at shallow depths below the fluvial deposits. The depth of overburden is unknown.

It appears from the above that there might be some initial degradation along the diversion route to More Creek. The prevailing slope of 0.00265 does, however, not exceed a clearly stable slope by much, so that the initial degradation would likely be minor and mainly restricted to the formation of a stream channel.

At the confluence with the south fork of More Creek, the slope of the diversion route increases abruptly by more than a factor of 3 to 0.00957, while the diversion flows would increase natural flows by a similar factor of somewhat over 3. For a lake outlet type channel to be stable at that discharge and on such a slope it would need to be armoured with 1000 mm material (D_{90})

which is unlikely to be available there, even at considerable depth.

Plate 5-10 can be used to see whether the steep, braided pattern of More Creek might persist even after diversions. The diversion would move the point representing the More Creek (south fork) from the centre of the scatter band of Plate 5-10 towards its upper edge without any significant increase in sediment supply from upstream. Therefore it is most unlikely that a braided channel would persist on the south fork of More Creek after regulation.

The probable sequence of events would be as follows:

During the first freshet season after diversion there would be considerable erosion and deposition along the diversion route to More Creek, resulting in the formation of an incised stream channel which might contain boulder rapids and other irregularities wherever it spills across terminal moraines or bedrock sills. In the vicinity of the confluence with More Creek there would be considerable degradation, changing the present braided channel to an entrenched single channel. Degradation would progress both upstream and downstream from the confluence area and this would provide the sediment supply needed to maintain the braided pattern further downstream along More Creek.

How far this degradation can progress would be uncertain, as it depends primarily on the type of materials that the degrading channel would encounter. After a few years the degradation would probably reach the divide and begin to reduce the water level in the diversion pool. No serious consequences would appear to be associated with these changes. Parts of the present channel zone of More Creek would become permanently dry and would slowly become vegetated.

5.6 SEDIMENTATION ASPECTS OF THE FORREST KERR CREEK DIVERSION - (Cont'd)

(d) Duration of the Initial Phase

The initial phase would end when significant amounts of coarse sediment begin to move across the divide and into the diversion channel. Exactly how much of the diversion pool volume would need to be filled with sediment for this to take place is difficult to estimate, but it is estimated to be less than one third of the volume, or $4 \times 10^6 m^3$.

Coarse sediment transport in Forrest Kerr Creek is unknown but the bed-load of the north fork of More Creek has been computed as approximately 200 000 t/yr, with an additional 200 000 t/yr of sand transported in suspension. Flows in Forrest Kerr Creek are comparable so that one can assume that the coarse sediment load might also be comparable. This indicates that the initial period might last approximately 10 years.

(e) The Long-term Equilibrium Phase

Towards the end of the initial period, sand would begin to move across the divide in a newly developed river channel on the delta deposited in the diversion pool by the two branches of Forrest Kerr Creek. This new river reach would be characterized by rapidly decreasing slope and decreasing grain size in the downstream direction. A major portion of the new channel would be characterized by a sand bed and almost negligible slope. Many comparable lake basins, filled recently by active gravel rivers exist in the Canadian Cordillera. The Vermilion Lakes area on the Bow River near Banff (Alberta) is one well known example.

The upstream gravel bed reach of Forrest Kerr Creek would gradually progress across the infilled diversion pool basin. Eventually gravel would begin to be carried across the divide, into the entrenched diversion channel formed during the initial phase, and the channel would begin to aggrade again. Based on the above bed-load estimates, it would take 20 to 50 years for this to occur.

Over the very long-term, one can expect the formation of a typical, highly braided proglacial channel from the snout of Forrest Kerr glacier to the More Creek reservoir. In the existing valley of Forrest Kerr Creek, such channel reaches have slopes of approximately 0.01, which should be close to the final slope backwards (upstream) from the south fork of More Creek (Plate 3-4). This would indicate a final water surface elevation of around 585.0 near the confluence of the two forks of Forrest Kerr Creek. The gravel volumes needed to fill the diversion pool to this level are, however, so large that it would be at least 100 years before presently proposed diversion dam crest at El. 570.0 would become inadequate.

5.7 RESERVOIR LIFE ESTIMATIONS

The Iskut River, Stikine River and More Creek all carry large amounts of suspended and bed-load material. The reservoirs formed for the projects would cause a large percentage of the suspended load and all of the bed-load to be trapped. The build-up of this material would eventually fill up the reservoir. To estimate the useful life of the reservoirs a number of assumptions must be made, the two major ones are listed below:

(a) Trap Efficiency

It is reasonable to assume that 100 percent of the bed-load would be trapped. Of the suspended load the sand and silt would be captured, while much of the clay material would remain in suspension and pass through the outlet facilities. For the present however, the conservative assumption was made that 100 percent of the material would be trapped.

5.7 RESERVOIR LIFE ESTIMATIONS - (Cont'd)

(b) Location of Deposition

Because of the large winter drawdowns expected in all the major reservoirs on the Stikine and Iskut rivers, deposition of bed-load at the upstream ends of the reservoirs would occur over an extended section of the reservoir bottom. Reservoir life calculations are based on the assumption that the suspended load would fill up the dead storage volume and subsequently the live storage volume. It is also assumed that the coarser bed-load material would be deposited only in the live storage volume.

Table 5-8 provides the estimates of reservoir life as calculated using the methods, data and assumptions outlined. The ratio between suspended sediment and bed-load transport varies from river to river. Because it appeared that bed-load transport in the upper Stikine and Klappan rivers would not be high, no test reaches were established on those rivers. Reservoir life calculations for Stikine Site Z reservoir are therefore based on the estimates of long-term suspended load only. From Table 5-8 it can be seen that bed-load transport represents 34 percent of the total load (by weight) at the More Creek Site and 2 percent (by weight) at the Iskut Canyon site. These values can be compared to values quoted by Szechowycz et al (1973).

> "Bed-load in the Colorado River is known to vary from 12 to 50 percent of the total sediment load. At Lake Mead and the Elephant Butte reservoir in the U.S., it was estimated that the bed-load represents about 15 percent of the measured suspended sediment load. The World Bank's study group estimated bed-load as 5 percent of the suspended sediment load in Indus River at the Tarbela damsite."

Table 5-8 shows that the Stikine Site Z and More Creek reservoirs might be expected to have lives extending over many hundreds of years. Forrest Kerr Diversion and Iskut Canyon reservoirs are likely, on the basis of the preliminary estimates of suspended and bed-load transport, to have much shorter lives. Since the economic viability of these projects may to some extent depend on the accuracy of the estimates of reservoir lives, the confirmation of the preliminary estimates by continuing programs of suspended- and bed-material sampling is strongly recommended.

SECTION 6.0 - TEMPERATURE AND ICE REGIME

6.1 TEMPERATURE

(a) Natural Conditions

Water temperatures were measured manually at seven WSC stations on the Stikine and Iskut rivers and their tributaries, on three occasions (June, August and September) in 1978 and on five occasions in 1979. In addition water temperatures were measured on the Chutine and Craig rivers in 1979.

In 1980 a program was initiated to collect a more in-depth survey of water temperatures. Thermographs are now installed at 13 locations in the basin and weekly spot measurements are being made at an additional seven locations.

The spot temperatures available to date have been plotted with the water temperatures collected by the Water Survey of Canada at their stations in the two basins during their routine measurements of streamflow. These latter have been assembled in a publication "Water Temperatures British Columbia and Yukon Territory" (Vols. 1 to 4) dated 1977. Combined with B.C. Hydro spot measurements these measurements have been plotted in the form of water temperature envelopes and appear on Plates 6-3 and 6-4.

The following general observations might be made on the natural temperature regime of the Stikine and Iskut rivers.

The Stikine River above the Grand Canyon appears to have temperatures of 0°C throughout the winter months November through April. During the open-water period, water temperatures increase from 0°C in early May to about 6°C in late May, 8 to 9°C in late June and, up to maximum temperatures from 10 to 15°C in July and

6.1 TEMPERATURE - (Cont'd)

August. During the autumn months, water temperatures in the Stikine River above Grand Canyon decrease from 8 to 9°C in early September through 5 to 8°C in late September, down to 2 to 4°C in late October. The temperature regime of the Klappan River is similar to that of the Stikine River.

At Telegraph Creek below the Grand Canyon, the Stikine River exhibits a temperature regime similar to that above the Grand Canyon, except that the temperatures during the summer months appear to be several degrees higher (9 to 10°C) in late June, 10 to 15°C in July and August, decreasing to 8 to 10°C in late September.

At Gauge No. 08CF001, Stikine River above Butterfly Creek, the short period of water temperature record indicates temperatures of 0°C during the winter months November to April rising to 8°C in late May to 9 to 10°C in late June, and up to maximum temperatures of 12 to 13°C in July and August. In September and October, temperatures decrease to a range of 2 to 9°C. The Chutine River water temperatures measured in 1979 indicate that this tributary with its flow from snow-fields and glaciers remains relatively cool, between 6 to 7°C, throughout May to July. This increment of cold water, combined with those of other smaller glacier-fed tributaries may have the effect of cooling the temperatures of the Stikine River main channel in its lower reaches.

The temperature of the Iskut River in its upper reaches shows, in the winter months, the moderating effect of the large lakes - Eddontenajon and Kinaskan - since temperatures for WSC Station No. 08CG003 Iskut River at outlet of Kinaskan Lake in the period December to April seldom descend to 0°C, remaining generally between 1 to 2°C, increasing by late June to 5 to 7°C and to maximum values between 10 to 14°C in July to August. In September

6.1 TEMPERATURE - (Cont'd)

water temperatures decrease to between 5 to 10°C and in October to between 4 to 8°C.

More and Forrest Kerr creeks which enter the Iskut River between Kinaskan Lake and the Iskut Canyon carry high volumes of glacial flow. More Creek water temperatures seldom rise above 9°C even in mid-July, and Forrest Kerr temperatures are even lower, seldom reaching 5°C in mid-July.

As a result, water temperatures in the Iskut River at Station No. 08CG004 - Iskut River below Snippaker Creek - which is below the Iskut Canyon damsite show the effect of these cold inflows. In winter months, (November to April) temperatures, from the fragmentary data collected, remain between 0 to 4°C. In May temperatures rise to 5 to 6°C, in June to 6 to 7°C and in July and August to maximum values of between 7 to 10°C. In September and October temperatures decrease to 2 to 8°C.

Craig River which enters Iskut River from the south between Snippaker Creek and the Stikine confluence appears to have temperatures warmer than those of the Iskut River itself, since at the end of July a temperature of over 13°C was recorded.

At Station No. 08CG001, Iskut River below Johnson River, a few kilometres upstream from the confluence of the Iskut River with the Stikine, the water temperature regime shows that in the months from November to March, the river remains between 0 to 2°C. In April and May, temperatures rise to between 2°C and 8°C, in June to between 7 and 9°C, and in July and August to maximum values of 6 to 12°C. In September and October, temperatures decrease to 4 to 8°C.

6.1 TEMPERATURE - (Cont'd)

The effect of relatively cold water from the Iskut entering the Stikine River just upstream from the Canada/U.S. border appears to augment the cooling effect of other smaller glacier-fed tributaries to the lower Stikine River, such as the Chutine, reducing summer water temperatures in the Stikine estuary below those recorded at Butterfly Creek. USGS Station 15024800 Stikine River near Wrangell indicates maximum temperatures in June and July reaching only 10°C. Winter temperatures appear to remain between 0 to 1°C.

During water-level measurements on the two test reaches - one on the lower Stikine River above Scud River, and one on the lower Iskut near the mouth of Craig River water temperatures were also measured during July to September 1979 in channels of the two rivers in order to determine variations of temperatures within the reaches.

Measurements made on the Lower Stikine Test Reach show for 28 August 1979 (the most complete set of temperature measurements) that temperatures in the larger active channels were uniformly a little higher than those measured upstream at the WSC gauge Stikine River above Butterfly Creek. Temperatures in smaller and less active channels reached values of over 16°C. On 22 September 1979 temperatures were close to 8°C.

Measurements made on the Lower Iskut Test Reach, for 29 August 1979 (the most complete set of temperature measurements) show that temperatures in the larger-active channels were 7 to 8°C, similar to those recorded at the WSC gauge Iskut River below Johnson River but at Section No. LI4, just below the mouth of glacial Hoodoo Creek, the water temperatures in the right bank channels were only 4 to 5°C. On 25 July 1979, temperatures in the same channels were somewhat higher, 8 to 12°C.

6.1 TEMPERATURE - (Cont'd)

(b) Post Project Conditions

For the feasibility study, no attempt was made to mathematically model the post-project thermal regimes of the Stikine and Iskut rivers.

The thermal regime of the Peace River downstream from G.M. Shrum Generating Station (G.M.S.) before and after completion of the project in 1968 has been examined in order to provide some analogy to the possible post-project conditions on the Stikine and Iskut rivers.

WSC Station No. 07EF001 - Peace River at Hudson Hope and 07FD002 - Peace River near Taylor record water temperatures in the Peace River downstream from G.M.S. Plate 6-2 shows temperature envelopes for the Peace River, at these two stations under both natural and regulated conditions. These envelopes show that during the months December to April temperatures generally remained at 0°C prior to construction of the Bennett Dam.

During June temperatures rose to between 9° and 11°C, and in July and August to maximum values of 15 to 21°C. In September, temperatures decreased to 8 to 12°C and in October to 2 to 8°C.

After completion of the project, winter temperatures at Hudson Hope appear to have increased to 2 to 4°C in the months December to April, and increase to 5 to 9°C in June, reaching maximum values of 8 to 18°C in July and August. In September, temperatures decreased to 10 to 12°C and in October to 9 to 11°C. At Taylor, some 110 km downstream, winter temperatures appear somewhat lower, 0 to 3°C from December to April, increase to 3 to 5°C in May, to 8°C in June, to reach maximum values of 11 to 17°C in July and August. In September temperatures decreased to 11 to 12°C and in October to 7 to 10°C.

6.1 TEMPERATURE - (Cont'd)

It appears that the regulation of the Peace River by G.M.S. has altered the thermal regime of the river as follows:

In winter, water temperatures in the reaches of the river near Hudson Hope are now 2 to 3°C higher than they were pre-project which accounts for the failure of the river to form an ice cover for varying distances downstream from G.M.S. Only in cold winters such as 1974 and 1979 has the ice cover progressed upstream from the B.C./Alberta border (160 km downstream from G.M.S.).

These spot measurements at the two W.S.C. stations are confirmed by discontinuous thermograph traces for 1976/77, 1977/78 and 1978/79 from the G.M.S. tailraces, from Peace Canyon and Site C which show a steady decline in temperatures from 9°C in October, through 6 to 7°C in November to 3 to 4°C in late December. In January to March, temperatures fluctuate between 1°C and 3°C.

In the summer months, there is some evidence that water temperatures in the Peace River reaches below G.M.S. have been lowered by a few degrees Celsius.

In October equally slight evidence indicates higher temperatures by several degrees.

For the Stikine and Iskut projects it appears likely that post-project temperature regime modifications would be of similar magnitude in view of the fairly deep reservoirs being created and the similarity of geographical latitude.

The thermal effects of the reservoirs will be reduced further downstream but will be complicated by the complex temperature regime of heavily-glaciated watersheds.

6.1 TEMPERATURE - (Cont'd)

To provide further analogies to the post-project thermal regime of the Stikine and Iskut projects, reference has been made to detailed studies of two recent projects in Siberia at a similar latitude.[8,9]

For these projects, accurate measurements were made of water temperatures upstream and downstream from the powerhouses, for the operating period 1964 to 1966 for Bratsk and for the reservoir filling period 1974 to 1976 for Ust-Ilim.

The measured temperatures over these periods were plotted in the form of isotherms on a time base. Concurrent monthly mean air temperatures for an adjacent meteorological station for the same periods were also presented. These graphs showed that for Bratsk reservoir, which was created on the Angara River downstream from Lake Baikal the following yearly thermal regime cycle is observed:

From January to May, the reservoir exhibits a stable stratification with water temperatures near 0°C at the surface, and temperatures near those of the state of maximum density (~4°C) at depths of 60 to 70 m.

After the daily mean air temperature exceeds 0°C in mid-April the temperature of the water under the ice sheet begins to increase. This brings about an increase in water density of the surface layers and a convective circulation which gradually spreads into the deeper layers, and by early June causes a short period of isothermal conditions when the entire reservoir is at the temperature of maximum density (4°C). From June to October the surface water temperature increases to a maximum of about 15-20°C by mid-August, and stratification of the upper layers of

6.1 TEMPERATURE - (Cont'd)

the reservoir, with temperature gradients from 4°C at depths to 20-22°C at the surface set up in the reservoir. Towards the end of October, as temperatures of the surface layers approach 4°C, convective circulation again occurs which gradually extends through the entire depth until by early November a short period of isothermal conditions exist at 4°C. This is followed by the development of winter inverse stratification.

Graphs of water temperatures for the filling period Ust-Ilim Reservoir, which was created on the Angara River immediately downstream from Bratsk power station show a thermal regime cycle as follows:

Initial filling of the reservoir occurred during an abnormally cold period - October to December 1974 - during which water entering Ust-Ilim reservoir from Bratsk reservoir was intensively cooled and during which the bed of the future reservoir was highly chilled. The reservoir was therefore filled with cold-water masses which continued to be cooled throughout the winter, and by February 1975 resulted in water temperatures less than 0.1°C even at lower levels. In April 1975 the mean air temperature increased to above 0°C and the surface water temperature after the ice break-up began to rise above 0°C setting up convective mixing processes in the reservoir. By May 1975 isothermal temperatures at 4°C were set up in the reservoir to be followed by a summer temperature stratification with surface temperatures of 20 to 23°C and temperatures near the reservoir bed of 4 to 7°C. From September to mid-November 1975; an isothermal temperature distribution with temperatures close to 4°C was set up and after December 1975; winter stratification, set in with temperatures of 0°C under the ice sheet increasing to 3°C near the bed.

6.1 TEMPERATURE - (Cont'd)

After the second winter of operation, spring and fall isothermal and summer stratification conditions similar to those in 1975 were experienced.

Water temperature conditions in the Angara River downstream from Ust-Ilim reservoir were affected by the reservoir temperature regime, and by the outlet facilities in use - i.e. submerged outlets at El. 22.5 (near the bottom of the cooled winter temperatures, warmer summer temperatures) reservoir, or powerplant turbine intakes at El. 70.0 some 30 m below the level of the full reservoir (winter temperatures cooler, summer temperatures warmer).

For the Bratsk and Ust-Ilim projects and the Krasnayarsk project, large unfrozen areas have been observed downstream from the powerplants decreasing from 200 km long at the beginning of winter to as little as 60 to 70 km during cold spells.

Similar thermal regimes in the Stikine and Iskut reservoirs and in the downstream reaches of the Stikine and Iskut rivers may be expected in view of the similarity of the annual air temperatures for the Siberian stations with those for Dease Lake. However, the relatively high drawdowns contemplated for the Stikine and Iskut reservoirs may tend to decrease the winter water temperatures because the water drawn through the penstocks and outlet valves may come from layers close to the surface where winter temperatures are close to 0°C.

6.2 ICE REGIME

A study of the published records for the Water Survey of Canada gauges on the Stikine River reveals that the river is generally ice-covered from late October or early November until late April or

6.2 ICE REGIME - (Cont'd)

May. At Gauge No. 08CB001 - Stikine River above Grand Canyon - freeze-up occurs from 1 to 7 days earlier than it does at Gauge No. 08CE001 - Stikine River at Telegraph Creek - reflecting the higher altitude and greater distance from coastal maritime influences, while break-up at the Grand Canyon gauge occurs from 1 to 3 weeks later than it does at the Telegraph Creek gauge. The short period of record at Gauge No. 08CF001 - Stikine River above Butterfly Creek - appears to indicate that freeze-up generally occurs on the same date as at Telegraph Creek (although in the mild winter of 1976/77, it occurred almost a month later) while break-up occurs from 1 to 5 days earlier than at Telegraph Creek.

A study of the published records for the three Water Survey of Canada gauges on the Iskut River - No. 08CG003 at the outlet of Kinaskan Lake, No. 08CG004 above Snippaker Creek, and No. 08CG001 below Johnson River, and for the W.S.C. Gauges on the tributaries - No. 08CG005, More Creek near the mouth, and No. 08CG006, Forrest Kerr Creek above 460 m Contour, shows that the Iskut River is generally ice-covered from late November or early December to late March or early April, while More and Forrest Kerr creeks are ice-covered from early November to late April or early May.

From observations of ice formation and break-up in the Stikine and Iskut basins carried out in the winter of 1978, 1979 and 1980 the following sequence of events was seen to occur:

1. As temperatures decrease in the autumn below the freezing level of 0°C, ice appears in its three principal forms, frazil, anchor and surface (sheet) ice. Frazil ice forms in water which has been supercooled by at least a few thousandths of a degree, and forms in great volumes in turbulent water where the entire body of water is cooled uniformly, as in rapids. When frazil ice forms in reaches in which the velocity is less than 0.6 m/s the frazil

particles pass under the ice cover and continue downstream often forming hanging dams at obstructions or constrictions.

2. Sheet ice forms readily on water flowing at velocities lower than 0.6 m/s due to the accumulation of frazil particles and is thus much in evidence out from the shores of rivers, but it forms on water at velocities greater than 0.6 m/s only if the ambient air temperature remains below -18°C for several days.

3. Anchor ice is formed on the river bottom on cold clear nights when back radiation from the water to the atmosphere reaches high values. It floats to the surface during daylight and often carries gravel and rocks downstream with it.

Break-up of ice on the Stikine and Iskut rivers, as with most northern rivers, starts with the commencement of runoff on the snow-covered basin as annual solar radiation reaches values high enough to melt the snow cover at the lower elevations. The discharge of the river starts to increase, putting the ice cover under uplift pressure. With increasing discharge, the ice cover fractures and starts to move downstream through rapid sections accumulating in front of solid ice reaches in the form of jams. The jams build and exert pressure against the stable cover which gradually gives way. With increasing discharges and temperatures, the entire ice cover fractures and moves downstream.

SECTION 7.0 - RECOMMENDATIONS

7.1 HYDROLOGY

The following recommendations are made regarding the hydrology studies program:

1. Continue the hydrologic, climatologic, snow course and glaciology data collection and monitoring programs in the Stikine-Iskut drainage basin.

2. Review the generated monthly streamflow values for the 35-year period used in the SHRUMO analysis with particular emphasis on the effect of the glaciated portions of the Iskut basin.

3. Establish new continuous streamflow gauging sites on the Pitman, Spatsizi and upper Stikine rivers. Data from these stations as well as data from the new climatological stations in the Stikine-Iskut basin will be used in the mathematical basin model for flood studies.

4. Revise estimates of Probable Maximum Flood and Spillway Design Discharges for all projects using updated data.

7.2 SEDIMENTATION ASPECTS

The following recommendations are made regarding the sedimentation aspects:

1. Continue sedimentation sampling program at all WSC gauging stations.

2. Establish new test reaches on the Stikine River near Winter Creek and on the Iskut River near Snippaker Creek.

7.2 SEDIMENTATION ASPECTS - (Cont'd)

3. Conduct a spot measurement suspended sediment sampling program on typical tributaries for each of the major regions of the basin.

4. Reassess the impact of the projects on all test reaches. Review estimations of useful reservoir life.

7.3 TEMPERATURE AND ICE REGIME

1. Complete installation of thermographs at all WSC stations. Install thermographs and/or take spot temperature measurements on typical tributaries in each major region of the watershed.

2. Use appropriate computer modelling techniques to make preliminary estimates of reservoir thermal balance and of the impact of the projects on downstream temperature regime.

3. Continue ice monitoring program to gather data pertinent to the diversion during construction and anticipated environmental impacts.

REFERENCES

1. Stichling, W. 1974. Sediment Load in Canadian Rivers. Inland Waters Directorate. Water Resources Branch, Ottawa. Bulletin No. 74.

2. Chuch, Michael. 1975. Implementation of Bed-load Sediment Transport Formulae for computation on Gravel Rivers, Using Mean Values of Hydraulic Geometry. Report prepared for Kellerhals Engineering Services Ltd.

3. Einstein, H.A. 1950. The Bed-load Function for Sediment Transportation in Open Channel Flow. U.S. Dept. of Agriculture, Soil Conservation Service. Techn. Bull. 1026. 78 pp.

4. Kellerhals, Rolf. 22-28 June 1980. River Regulation and Channel Stability. Paper presented to the International Workshop on Engineering Problems in the Management of Gravel-bed Rivers held at Gregynog, Wales, U.K.

5. Kellerhals, Rolf. 1967. Stable Channels with Gravel-paved Beds. Journal of the Waterways of Harbors Division ASCE. v. 90, No. WW1, pp. 63-84.

6. Szechowycz, R.W. and M.M. Qureshi. September 1973. Sedimentation in Mangla Reservoir. Journal of the Hydraulics Division ASCE.

7. Grigore and Sokolnikon. October 1973. Ice Thermal Reservoir Regime First Years of Operation of the Krasnoyarsh Hydroelectric Plant. Gibrotekhnicheskoe Stroitelstvo No. 10.

8. Rassorenor, F.F. July 1968. Thermal Regime of the Bratsk Reservoir Dam Site. Gribrotekhnicheskoe Stroitelstvo No. 7.

9. Gotlib, Y.L., M.V. Gorina and A.K. Kotukhova. February 1978. Hydrothermal Regime Above and Below the Ust-Ilim Reservoir during its Filling. Gribrotekhnicheskoe Stroitelstvo No. 2.

10. Vanicek, Petr and Dezsö Nagy. 1980. The Map of Contemporary Vertical Crustal Movements in Canada. EOS, Trans. Am-Geophys. Union. v. 61, No. 14, pp. 145-147.

11. Hollingshead, A.B. 1971. Sediment Transport Measurements in a Gravel River. Journal of the Hydraulic Division, ASCE. v. 97, no. HY11, 1817-1834.

12. Holland, S.S. 1976. Land Forms of British Columbia. B.C. Dept. of Mines and Petroleum Resources. Bull. No. 48.

TABLE 3-1

HYDROLOGY, RIVER REGIME AND MORPHOLOGY

Item	Project						
	Stikine Site Z	Stikine Tanzilla		Iskut Canyon		More Creek	
DAMS							
Principal - type	Concrete Arch	Concrete Arch		Concrete Arch		Concrete Arch	
- Max. height, (crest length) (m)	270 (375)	193 (530)		158 (892 + gravity)		135 (350)	
Secondary - type[1]	Earthfill	Alt. Earthfill		Alt. Earthfill		Alt. Earthfill	
- Max. height, (crest length) (m)	250 (470)	198 (460)		165 (620)		140 (280)	
SPILLWAY							
PMF design capacity (m^3/s)	7 645	7 645		5 680		1 580	
DIVERSION		Arch	Earth	Arch	Earth	Arch	Earth
- Design capacity (m^3/s)	2 440	2480	2630	1630	1870	500	530
- Return frequency (years)	15	15	30	15	30	15	30
RESERVOIR							
Max. flood level (m)	797	534		350		531	
Max. normal level (m)	794	531		347		528	
Average level (m)	779	531		332		506	
Min. level (m)	749	531		317		488	
Surface area (ha)	12 700	900		3 800		4 100	
Total storage ($m^3 \times 10^6$)	6 700	800		1 240		2 000	
Live storage ($m^3 \times 10^6$)	3 800	-		800		1 300	
AVG. TAILWATER LEVEL (m)	531.5	279.0		144.5		381.0	
POWER FACILITIES[2]							
Total plant capacity (MW)	915	915		780		155	
Units, no. and capacity (MW)	3-305	3-305		3-260		1-155	
Units, rotating speed (rpm)	200	200		200		200	
Rated net head (m)	258	241		194		143	
Total rated plant discharge (m^3/s)	404	434		458		123	

---

[1] This report analyzes only the principal project type, for discussion of Secondary Proposals see Section 8.0 to 11.0 in the Feasibility Study.

[2] Power facilities based on an approximate capacity factor of 65 percent for the Stikine River projects and 50 percent for the Iskut River projects.

TABLE 4-1

AVAILABLE METEOROLOGICAL DATA

Station No.	Station Name	Elevation (m)	Period of Record	Observing Program			Mean Values			
							Temperature			
				Temp.	Prec.	Rate of Rainfall	January (°C)	July (°C)	Year (°C)	Precipitation (mm)
1200R0A	Bob Quinn Lake	579	Sep/74 - Oct/74 Jan/78 - present	X	X		(1978) -13.3	+13.8	+2.2	579
1070915	Bowser Lake	366	May/56 - Aug/56	X	X		-	-	-	-
1191440	Cassiar	1078	Mar/53 - Jun/75 Jun/75 - present	X X	X X	X	# -10.3	+11.1	-2.7	706
1191442	Cassiar Mine	1854	Aug/60 - Aug/63	X	X		-	-	-	-
1201770	Cold Fish Lake	1293	Jul/55 - Aug/55 Jul/57 - Sep/62 (summers only)	X X	X X		-	-	-	-
1192340	Dease Lake	816	Sep/44 - Oct/45 Oct/46 - present	X X	X X		# -19.4	+12.8	-1.1	394
1202635	Echo Lake	1132	Oct/15 - Dec/24		X		-	-	-	600
1202638	Eddontenajon	884	Sep/72 - Oct/72	X	X		-	-	-	-
1203046	Galore Creek	798	Jan/66 - Nov/68 Jun/73 - Oct/73	X X	X X		(1968) -13.9	+12.8	-0.5E	2490 E
1193245	Good Hope Lake	770	Aug/73 - present	X	X		-12.8	+12.2	+0.5	470
1203648	Hyland Post	1067	Jan/64 - May/64 Oct/71 - Mar/72	X X	X X		-	-	-	-
1203670	Iskut	884	Aug/73 - Dec/73	X	X		-	-	-	-
1204215	Kinaskan Lake	816	Oct/66 - Dec/70 (continuous) Jun/71 - Sep/77 (summers only)	X X	X X		(1968) -16.1	+12.2	-0.5	550
1204958	McBride River	915	Apr/75 - Mar/78	X	X		(1976) -15.0	+11.1	-1.0	526
1194985	McDame Creek	-	Aug/37 - Mar/43		X		# -17.2	+13.3	-2.2	436
1206258	Porters Landing	732	Feb/72 - Jun/72	X	X		-	-	-	-
1066420	Premier	418	Jan/25 - Jun/49 Jan/51 - Apr/53	X X	X X		# -4.4	+13.9	+4.4	2000
1207125	Schaft Creek	915	Jun/69 - Sep/69 Jun/70 - Nov/73 May/74 - Oct/74	X X X	X X X		(1973) -13.9	+10.6	-1.7E	721
1070HG3	Sustut Mountain	1799	Jun/73 - Sep/74 (summers only)	X	X		-	-	-	-
1208040	Telegraph Creek	183	Jul/42 - Apr/58 Aug/60 - Feb/62 Oct/73 - Jun/75 Jun/75 - present	X X X X	X X X X	X	# -15.5	+15.5	+2.2	410
1208202	Todagin Ranch	899	Aug/73 - Jun/75 Jun/75 - present	X X	X X	X	(1976) -11.1	+10.8	0	431
1208295	Tulsequah	-	Aug/64 - Nov/64 Dec/64 - Sep/66	X X	X X	X	(1965) -9.4	+14.4	2.8	2827

= long-term means

(Year): means for short period of record for the year indicated

TABLE 4-2

LIST OF SNOW COURSES IN AND NEAR THE STIKINE RIVER BASIN

No.	Snow Course	Elevation (m)	Record Began	Mean Water Equivalent on April 1 1980	Mean Water Equivalent on April 1 Mean to 1980
137	Pulpit Lake	1310	1963	297	397
138	Fredrickson Lake	1310	1963	178	253
139	Trygve Lake	1400	1963	279	352
147	Dease Lake	820	1964	134	138
148	Cassiar	1390	1964	334	306
259	Telegraph Creek	530	1974	179	163
260	Iskut	1000	1974	122	174
261	Ningunsaw Pass	690	1974	308	426
262	Bear Pass	460	1974	383	618
263	Granduc Mine	790	1974	1378	1386
291	Metahag Creek	1220	1980	286	-
292	Beatty Creek	1130	1980	294	-
293	Tahltan Lake	1220	1980	404	-
294	Triumph Creek	1220	1980	1018	-
295	Schaft Creek	1140	1980	505	-
296	Forrest Kerr Creek	560	1980	531	-
297	Snippaker Creek	620	1980	601	-
298	Tumeka Creek	1220	1980	517	-
299	Kinaskan Lake	1020	1980	381	-
300	Eaglenest Creek	1540	1980	279	-
301	Upper Stikine	1450	1980	362	-
302	Frog River	1480	1980	298	-
303	Wade Lake	1370	1980	317	-

TABLE 4-3

PROBABLE MAXIMUM ACCUMULATED SNOWFALL

River	Project	Method	Estimated Maximum Snow Accumulation / Recorded Mean Snow Accumulation
Stikine	Site Z	Partial Season - 4 day duration (reduced by 1.6 factor)	4.03[1]
		1 in 10 000 year Snow Course	3.25[1]
Peace	Bennett	Partial Season - 3 day duration	1.94[2]
Peace	Bennett	Snowstorm Maximization	1.93[2]
Yukon	Rampart	Maximum-to-mean relation	3.00[3]
Yukon	Rampart	Partial Season - 1 month duration	2.80[3]
Kootenay	-	-	2.2[4]
Columbia	Mica	Partial Season - 1 month duration	2.28[5]
Duncan	Duncan	Partial Season - 1 month duration	1.97[5]
Columbia	Arrow	Partial Season - 1 month duration	2.05[5]

---

[1] Hogg, W.D., Critical Meteorological Conditions for Maximum Inflow, Stikine River, B.C., above Grand Canyon, 1980.

[2] Bruce, Richards, and Sporns, Critical Meteorological Conditions for Maximum Infow, Wind Set-up and Waves Portage Mountain Reservoir, Peace River, B.C., 1965.

[3] U.S. Weather Bureau, Hydrometeorological Report No. 42 Meteorological Conditions for the Probable Maximum Flood on the Yukon River above Rampart, Alaska, 1966.

[4] Snyder, Report on Review of Spillway Design Flood Derivations for Portage Mountain Dam, Peace River, B.C., 1965.

[5] Caseco Consultants Ltd., Columbia River Studies Probable Maximum Floods for Mica, Arrow, and Duncan Projects, 1964.

TABLE 4-4

AREAS FOR FLOW GENERATION

Gauge or Site	Drainage Area Above (km²)	Ratio Used	Gauge used to Generate Flow	Mean Annual Flows 1940-75 (m³/s)	Mean Annual Flows 1928-76 (m³/s)
Stikine Basin					
WSC Gauge No. 08CB001 (above Grand Canyon)	18 800	-	-	279.6	276.2
Site Z	19 400	1.02466	08CB001	286.5	283.0
Tanzilla	19 800	1.04247	08CB001	291.8	287.9
Iskut Basin					
WSC Gauge No. 08CG004 (Iskut below Snippaker)	7 250	-	-	261.9	262.6
Iskut Canyon	6 900	0.96	08CG004	251.4	252.1
WSC Gauge No. 08CG005 (More Creek near the mouth)	890			48.7	49.3
More Creek damsite	890	1.00	08CG005	48.7	49.3
WSC Gauge No. 08CG006 (Forrest Kerr Creek near 460 m contour)	312	-	-	22.7	22.9
Forrest Kerr Creek Diversion Dam	283	0.91	08CG006	20.7	20.8

TABLE 4-5

MONTHLY AVERAGE STREAMFLOWS AT PROJECT SITES[1]
(m^3/s)

Month	Project			
	Site Z	Tanzilla	Iskut Canyon	More Creek[2]
January	46.1	46.9	36.8	8.3
February	37.1	37.7	27.6	6.4
March	31.3	31.8	28.9	6.3
April	51.6	52.5	51.1	10.1
May	455.4	463.3	261.0	48.0
June	1055.0	1073.3	623.6	157.1
July	703.9	716.2	682.6	203.4
August	385.7	392.4	549.4	195.1
September	274.4	279.2	315.7	96.9
October	218.4	223.8	248.0	58.1
November	110.6	114.7	130.5	29.5
December	69.0	70.2	61.3	13.5
AVERAGE FOR YEAR	286.5	291.8	251.4	69.4

---

[1] For 35-year period July 1940 to June 1975.

[2] Includes Forrest Kerr Creek Diversion.

TABLE 5-1

SUSPENDED SEDIMENT SAMPLING SUMMARY
1978 - 1979

Date	Time (PST)	Instantaneous Discharge (m^3/s)	Water Temperature (°C)	Suspended Sediment Concentration (mg/L)	Suspended Sediment Discharge (t/d)
MORE CREEK NEAR THE MOUTH (Station No. 08CG005)					
3 June 1978	0900	101	3.3	526	4610
5 June 1978	1140	125	5.9	583	6300
2 August 1978	1110	134	6.0	606	7000
20 September 1978	1325	33.1	5.5	82	235
18 March 1979	1220	6.03	-	8	5
16 May1979	1130	34.3	4.0	14	42
23 May 1979	0945	66.5	4.0	207	1190
11 June 1979	1600	73.6	4.0	83	529
19 June 1979	1340	130	6.7	781	8780
11 July 1979	1730	161	9.0	594	8290
24 July 1979	0855	131	5.0	581	6580
27 August 1979	1145	103	6.3	378	3360
12 September 1979	1315	66.5	4.5	158	907
1 November 1979	1025	18.4	1.5	12	19
FORREST KERR CREEK AT 460 m CONTOUR (Station No. 08CG006)					
3 June 1978	1210	30.6	5.3	179	474
5 June 1978	1425	69.1	-	277	1660
2 August 1978	1550	156	2.0	562	7580

TABLE 5-1 - (Cont'd)

SUSPENDED SEDIMENT SAMPLING SUMMARY
1978 - 1979

Date	Time (PST)	Instantaneous Discharge (m^3/s)	Water Temperature (°C)	Suspended Sediment Concentration (mg/L)	Suspended Sediment Discharge (t/d)
FORREST KERR CREEK AT 460 m CONTOUR (Station No. 08CG006)					
20 September 1978	0955	27.0	1.5	108	252
18 March 1979	0840	4.67	0.1	0	0
16 May 1979	0750	8.38	1.5	13	9
23 May 1979	1405	16.5	3.5	37	53
24 May 1979	0935	18.8	2.5	100	162
11 June 1979	1855	36.2	4.0	220	689
20 June 1979	1150	46.7	2.9	195	788
11 July 1979	2030	108	2.0	396	3690
24 July 1979	1415	136	3.0	453	5350
27 August 1979	1445	67.1	2.0	293	1700
10 September 1979	1820	69.9	0.5	159	962
31 October 1979	1715	8.72	0.5	64	48
ISKUT RIVER ABOVE SNIPPAKER CREEK (Station No. 08CG004)					
3 June 1978	1610	578	8.5	806	40300
6 June 1978	0910	745	-	962	62000
2 August 1978	1720	716	10.5	874	54200
20 September 1978	1115	232	6.0	144	2880
18 March 1979	0925	79.3	-	9	62

TABLE 5-1 - (Cont'd)

SUSPENDED SEDIMENT SAMPLING SUMMARY
1978 - 1979

Date	Time (PST)	Instantaneous Discharge (m^3/s)	Water Temperature (°C)	Suspended Sediment Concentration (mg/L)	Suspended Sediment Discharge (t/d)
ISKUT RIVER ABOVE SNIPPAKER CREEK (Station No. 08CG004)					
24 May 1979	1010	507	5.5	797	34900
20 June 1979	1320	617	7.9	182	9710
20 June 1979	1321	617	7.9	187	9980
25 July 1979	0905	801	8.6	743	51500
31 August 1979	1355	470	-	216	8780
1 November 1979	1400	115	3.0	23	230
CRAIG RIVER NEAR THE MOUTH (B.C. Hydro Section)					
24 June 1979	1300	95.4	6.0	165	1360
29 July 1979	1355	119	8.0	311	3210
23 September 1979	1100	36.0	5.6	79	246
ISKUT RIVER BELOW JOHNSON RIVER (Station No. 08CG001)					
4 June 1978	1150	940	7.6	880	71600
6 June 1978	1200	997	-	670	57800
3 August 1978	1215	1350	6.5	1030	121 000
24 September 1978	0930	222	5.0	57	1100
17 March 1979	1535	84.1	1.0	6	44
16 May 1979	1705	320	5.0	80	2210
28 May 1979	1805	575	6.9	276	1370

TABLE 5-1 - (Cont'd)

SUSPENDED SEDIMENT SAMPLING SUMMARY
1978 - 1979

Date	Time (PST)	Instantaneous Discharge (m^3/s)	Water Temperature (°C)	Suspended Sediment Concentration (mg/L)	Suspended Sediment Discharge (t/d)
ISKUT RIVER BELOW JOHNSON RIVER (Station No. 08CG001)					
12 June 1979	1300	719	7.0	215	13300
24 June 1979	1620	833	7.7	232	16700
12 July 1979	1120	1320	6.0	626	71600
29 July 1979	1010	1180	7.0	516	52600
29 August 1979	1145	889	6.2	228	17500
11 September 1979	1505	575	-	51	2540
24 September 1979	0920	430	10.0	189	7040
31 October 1979	1430	182	-	55	866
KLAPPAN RIVER NEAR TELEGRAPH CREEK (Station No. 08CC001)					
1 August 1978	1350	117	13.0	328	3320
23 September 1978	1435	44.2	4.3	8	31
25 May 1979	1100	121	6.1	210	2200
12 June 1979	1855	170	6.0	126	1850
22 June 1979	1735	223	8.0	119	2300
26 July 1979	1045	189	-	164	2680
26 August 1979	1250	110	12.0	220	2090
30 August 1979	1035	89.2	7.9	103	795
10 October 1979	1140	108	2.0	217	2030

TABLE 5-1 - (Cont'd)

SUSPENDED SEDIMENT SAMPLING SUMMARY
1978 - 1979

Date	Time (PST)	Instantaneous Discharge (m^3/s)	Water Temperature (°C)	Suspended Sediment Concentration (mg/L)	Suspended Sediment Discharge (t/d)
STIKINE RIVER ABOVE GRAND CANYON (Station No. 08CB001)					
27 June 1978	1345	586	9.0	54	2740
1 August 1978	1035	272	14.5	45	1060
23 September 1978	1220	195	4.8	3	51
25 May 1979	1530	699	5.3	451	27300
28 May 1979	0955	833	-	216	15500
13 June 1979	1345	881	4.0	118	8990
21 June 1979	1515	1360	8.0	603	70800
26 July 1979	1430	583	-	61	3080
25 August 1979	1145	265	12.0	56	1280
31 August 1979	0840	211	10.7	51	934
8 October 1979	1620	215	0.5	7	130
CHUTINE RIVER BELOW WRIGGLE CREEK (B.C. Hydro Section)					
27 May 1979	1150	157	5.8	104	1420
22 June 1979	1200	251	6.7	122	2650
30 July 1979	1015	413	6.0	382	13700
STIKINE RIVER ABOVE BUTTERFLY CREEK (Station No. 08CF001)					
27 June 1978	1745	1640	10.0	127	18100
3 August 1978	1525	1050	12.0	483	43800

TABLE 5-1 - (Cont'd)

SUSPENDED SEDIMENT SAMPLING SUMMARY
1978 - 1979

Date	Time (PST)	Instantaneous Discharge (m^3/s)	Water Temperature (°C)	Suspended Sediment Concetration (mg/L)	Suspended Sediment Discharge (t/d)
STIKINE RIVER ABOVE BUTTERFLY CREEK (Station No. 08CF001)					
24 September 1978	1220	320	5.6	20	533
29 May 1979	1230	1950	7.8	595	100 000
12 June 1979	1315	1640	8.0	309	43900
23 June 1979	1310	2290	10.2	402	79500
28 July 1979	1410	1480	13.2	281	35800
22 August 1979	1420	875	11.0	234	17700
28 August 1979	0835	943	16.3	230	18800
22 September 1979	0945	538	10.4	67	3120
7 October 1979	1500	569	3.0	83	4080
STIKINE RIVER NEAR WRANGELL, ALASKA (Station No. 15024800)					
20 October 1975	1700	1040	4.0	84	7550
3 June 1976	1500	1910	8.0	169	27900
28 July 1976	1650	3110	8.5	144	39200
4 March 1977	1200	286	2.0	14	347
22 April 1977	1200	456	7.0	16	631
13 June 1977	1630	4810	10.5	1140	474 000
18 August 1977	1800	4250	8.5	417	153 000
21 September 1977	1730	1230	7.0	114	12200

TABLE 5-1 - (Cont'd)

SUSPENDED SEDIMENT SAMPLING SUMMARY
1978 - 1979

Date	Time (PST)	Instantaneous Discharge (m^3/s)	Water Temperature (°C)	Suspended Sediment Concetration (mg/L)	Suspended Sediment Discharge (t/d)
STIKINE RIVER NEAR WRANGELL, ALASKA (Station No. 15024800)					
17 November 1977	1430	439	.0	15	570
20 January 1978	1530	164	.0	1	15
28 April 1978	1330	1010	5.0	153	13300
15 June 1978	1605	2920	9.5	276	69700
21 August 1978	1630	2500	8.0	172	37200
1 November 1978	1500	2740	2.5	207	49000
22 January 1979	1500	188	.5	13	211
19 March 1979	1100	211	.5	12	220
13 June 1979	1340	2940	8.5	212	54000
13 July 1979	1200	4640	8.5	393	158000
8 August 1979	1410	2890	9.0	175	43700
8 September 1979	1200	1600	8.0	200	27700
6 November 1979	-	368	-	47	1490

TABLE 5-2

SUSPENDED SEDIMENT LOAD SUMMARY
1978

MEASURING STATION	STATION NUMBER	MONTHLY SUSPENDED SEDIMENT LOAD IN TONNES						TOTAL SUSPENDED SEDIMENT LOAD APRIL TO SEPT (TONNES)	1978 ESTIMATED ANNUAL LOAD (TONNES)
		APRIL	MAY	JUNE	JULY	AUGUST	SEPT		
MORE CREEK NEAR THE MOUTH	08CG005	240	7,000	124,000	143,000	146,000	16,000	436,000	626,000
FORREST KERR CREEK ABOVE 460 m CONTOUR	08CG006	90	2,000	39,000	115,000	119,000	16,000	291,000	316,000
ISKUT RIVER ABOVE SNIPPAKER CREEK	08CG004	3,000	62,000	1,615,000	1,120,000	978,000	132,000	3,910,000	4,892,000
ISKUT RIVER BELOW JOHNSON RIVER	08CG001	4,000	89,000	1,262,000	1,536,000	1,770,000	224,000	4,885,000	8,562,000
KLAPPAN RIVER NEAR TELEGRAPH CREEK	08CC001	690	8,000	537,000	246,000	71,000	6,000	869,000	883,000
STIKINE RIVER ABOVE GRAND CANYON	08CB001	85	5,000	228,000	77,000	50,000	8,000	368,000	380,000
STIKINE RIVER ABOVE BUTTERFLY CREEK	08CF001	1,000	47,000	707,000	741,000	678,000	91,000	2,265,000	2,435,000
STIKINE RIVER NEAR WRANGELL, ALASKA	15024800	52,000	468,000	2,546,000	2,388,000	2,193,000	390,000	8,037,000	10,432,000

TABLE 5-3

SUSPENDED SEDIMENT LOAD SUMMARY
1979

MEASURING STATION	STATION NUMBER	MONTHLY SUSPENDED SEDIMENT LOAD IN TONNES						TOTAL SUSPENDED SEDIMENT LOAD APRIL TO SEPT (TONNES)	1979 ESTIMATED ANNUAL LOAD (TONNES)
		APRIL	MAY	JUNE	JULY	AUGUST	SEPT		
MORE CREEK NEAR THE MOUTH	08CG005	870	17,000	122,000	228,000	118,000	41,000	527,000	574,000
FORREST KERR CREEK ABOVE 460 m CONTOUR	08CG006	30	2,000	23,000	109,000	92,000	24,000	250,000	303,000
ISKUT RIVER ABOVE SNIPPAKER CREEK	08CG004	34,000	420,000	720,000	1,589,000	768,000	341,000	3,872,000	4,316,000
ISKUT RIVER BELOW JOHNSON RIVER	08CG001	21,000	308,000	721,000	1,898,000	837,000	476,000	4,261,000	6,364,000
KLAPPAN RIVER NEAR TELEGRAPH CREEK	08CC001	200	29,000	116,000	161,000	62,000	22,000	390,000	418,000
STIKINE RIVER ABOVE GRAND CANYON	08CB001	200	215,000	995,000	475,000	58,000	50,000	1,793,000	1,890,000
STIKINE RIVER ABOVE BUTTERFLY CREEK	08CF001	3,000	688,000	2,709,000	1,804,000	570,000	171,000	5,945,000	6,355,000
STIKINE RIVER NEAR WRANGELL, ALASKA	15024800	56,000	779,000	3,144,000	4,635,000	2,346,000	1,839,000	12,799,000	15,536,000

* 1979 USGS DATA NOT AVAILABLE

TABLE 5-4

LONG TERM SUSPENDED SEDIMENT LOAD CALCULATIONS
STIKINE RIVER BASIN

DURATIONS		KLAPPAN RIVER NEAR TELEGRAPH CREEK (3550 km²) SEE PLATE 2-1			STIKINE RIVER ABOVE GRAND CANYON (18,800 km²) SEE PLATE 2-1			STIKINE RIVER ABOVE BUTTERFLY CREEK (36,000 km²) SEE PLATE 2-1			STIKINE RIVER NEAR WRANGELL, ALASKA (49,700 km²) SEE PLATE 2-1		
%	DAYS n	Q m³/sec	C mg/l	L Tonnes QxCxnx.0864	Q m³/sec	C mg/l	L Tonnes QxCxnx.0864	Q m³/sec	C mg/l	L Tonnes QxCxnx.0864	Q m³/sec	C mg/l	L Tonnes QxCxnx.0864
.2	1.28	470	2213	114937	2090	2364	545976	3620	1066	426428	7130	1166	918687
.5	1.46	428	1826	98507	1890	1876	446907	3030	806	307822	6340	984	786333
1.0	2.74	374	1390	122972	1660	1406	552095	2710	676	433347	5770	859	1172436
2.0	7.30	323	1032	210075	1390	942	825198	2410	563	855102	4920	683	2117767
5.0	14.60	259	662	216113	972	424	519463	1950	406	997890	4360	572	3143438
10.0	27.38	199	386	181570	828	295	577372	1600	299	1130822	3600	434	3693135
20.0	36.50	142	194	86807	535	111	167128	1160	180	657950	2890	315	2868605
30.0	36.50	92.6	82	23927	367	48	55510	797	100	251143	2130	203	1362506
40.0	36.50	61.2	35	6750	264	23	19133	534	54	90865	1500	122	576652
50.0	63.88	35.4	12	2343	175	9	8686	289	21	33470	863	55	261763
75.0	91.24	11.4	1	90	47.7	0	0	98.3	4	3097	216	7	11910
100.0	45.62	6.17	0	0	19.8	0	0	63.1	2	487	127	3	1601
TOTALS	365			1,064,091			3,737,468			5,188,423			16,914,732
ANNUAL SEDIMENT PRODUCTION RATE (t/km²)				300			198			144			340

TABLE 5-8

LONG TERM SUSPENDED SEDIMENT LOAD CALCULATIONS
ISKUT RIVER BASIN

DURATIONS		MORE CREEK NEAR THE MOUTH ($790\ km^2$) SEE PLATE 2-1			FORREST KERR CREEK ABOVE [illegible] m CONTOUR ($311\ km^2$) SEE PLATE 2-1			ISKUT RIVER ABOVE SHIPPAKER CREEK ($7230\ km^2$) SEE PLATE 2-1			ISKUT RIVER BELOW JOHNSON RIVER ($9350\ km^2$) SEE PLATE 2-1		
%	DAYS n	Q m^3/sec	C mg/l	L Tonnes QxCxnx.0864	Q m^3/sec	C mg/l	L Tonnes QxCxnx.0864	Q m^3/sec	C mg/l	L Tonnes QxCxnx.0864	Q m^3/sec	C mg/l	L Tonnes QxCxnx.0864
.2	1.28	399	3986	175783	167	592	10927	1430	3680	581634	2440	2567	692142
.5	1.46	275	2068	71695	159	566	11345	1270	2935	469916	2040	1862	478776
1.0	2.74	247	1722	100632	147	529	18398	1130	2377	635498	1800	1475	628036
2.0	7.30	210	1289	170628	129	475	38624	1000	1894	1193874	1600	1194	1203973
5.0	14.60	162	816	166653	104	359	47069	844	1384	1472608	1390	922	1615356
10.0	27.38	130	556	170886	83.0	324	63579	725	1044	1789483	1170	676	1869543
20.0	36.50	94.9	320	95712	56.6	233	41564	552	630	1096045	889	414	1159750
30.0	36.50	62.3	153	30042	32.8	146	15093	385	323	391933	668	247	519919
40.0	36.50	36.0	58	6581	16.3	80	4110	249	144	113008	464	128	187150
50.0	63.88	19.2	19	2012	7.87	43	1867	144	52	41303	289	54	86065
75.0	91.24	6.68	3	158	2.01	13	206	37.1	4	1169	91.2	7	5029
100.0	45.62	2.58	1	10	.54	4	9	16.0	1	63	27.8	1	109
TOTALS	365			990,792			252,791			7,786,534			8,445,848
ANNUAL SEDIMENT PRODUCTION RATE (t/km^2)				1250			813			1080			903

TABLE 5-6

SUSPENDED SEDIMENT LOAD BALANCE

MEASURING STATION	DRAINAGE AREA km^2	TOTAL SUSPENDED LOAD FOR 1978 PERIOD OF MEASUREMENT APRIL-SEPT Tonnes	1978 ESTIMATED ANNUAL LOAD SEE TABLE 5-2 Tonnes	TOTAL SUSPENDED LOAD FOR 1979 PERIOD OF MEASUREMENT APRIL-SEPT Tonnes	1979 ESTIMATED ANNUAL LOAD SEE TABLE 5-3 Tonnes	LONG TERM ANNUAL LOAD ESTIMATES Tonnes	ANNUAL SEDIMENT PRODUCTION RATE Tonnes/km^2
1. MORE CREEK NEAR THE MOUTH	790	436,000	626,000	527,000	574,000	991,000	1250
2. FORREST KERR CREEK ABOVE 460 m CONTOUR	311	291,000	316,000	250,000	303,000	253,000	813
3. ISKUT RIVER ABOVE SNIPPAKER CREEK	7230	3,910,000	4,892,000	3,872,000	4,316,000	7,787,000	1060
4. ISKUT RIVER BELOW JOHNSON RIVER	9350	4,885,000	8,562,000	4,261,000	6,364,000	8,446,000	903
5. KLAPPAN RIVER NEAR TELEGRAPH CREEK	3550	869,000	883,000	390,000	418,000	1,064,000	300
6. STIKINE RIVER ABOVE GRAND CANYON	18,800	368,000	380,000	1,793,000	1,890,000	3,737,000	199
7. STIKINE RIVER ABOVE BUTTERFLY CREEK	36,000	2,265,000	2,435,000	5,945,000	6,355,000	5,188,000	144
8. SUM OF 4 AND 7	45,400	7,150,000	10,997,000	10,206,000	12,719,000	13,634,000	-
9. STIKINE RIVER NEAR WRANGELL, ALASKA	49,700	8,037,000	10,432,000	12,799,000	15,536,000	16,815,000	340

TABLE 5-7

BEDLOAD TRANSPORT SUMMARY

Location of Test Reach	Cross Section Number	Velocity[3] (m/s)	Maximum Hydraulic[3] Radius (m)	Annual Total Load (t)
Upper Iskut (See Plate 5-5)	1	3.9	3.5	62 000
	2	4.1	2.5	127 000
	3	4.1	1.6	(3 000)
	4	4.3	1.7	27 000
	5	5.4	2.8	(272 000)
	Average[1]	4.3	2.4	72 000
More Creek (See Plate 5-4)	1	3.3	1.1	102 000
	2	3.1	1.2	46 000
	3	4.7	1.1	335 000
	4	6.3	1.5	773 000
	5	4.8	0.7	141 000
	Average[1]	4.7	1.0	280 000
Lower Stikine (See Plate 5-7)	1	2.5	4.7	117 000
	2	2.1	3.1	134 000
	3	1.9	3.8	4 000
	4	1.4	4.9	4 000
	Average[2]	1.9	3.9	23 000

---

[1] Average calculated by averaging loads without bracketed values, which are regarded as unrealistic.

[2] Average calculated using an average hydraulic section.

[3] These hydraulic characteristics correspond to the .2 percent probable streamflow as determined by the daily flow probability analysis.

TABLE 5-8

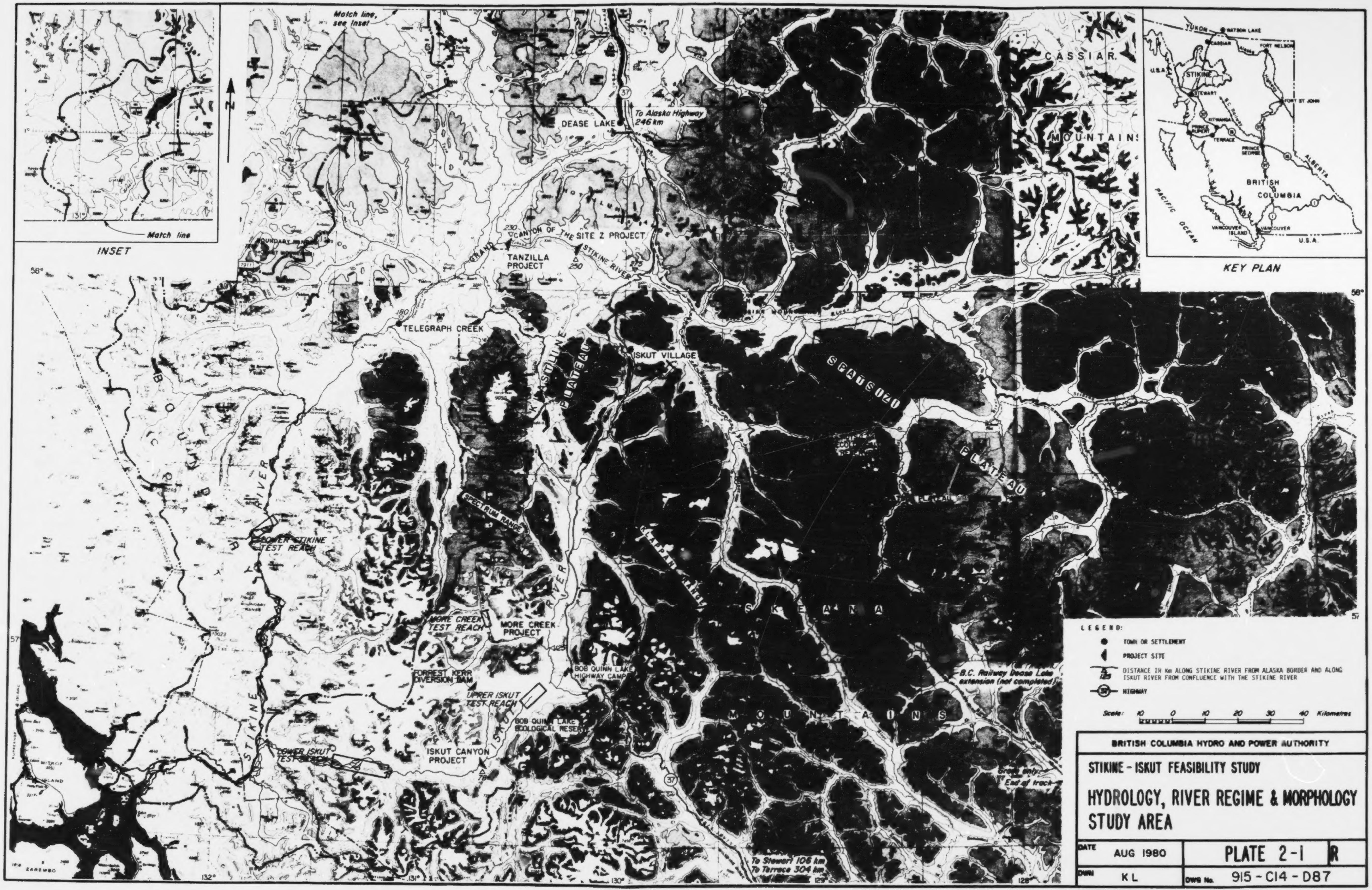
ESTIMATIONS OF RESERVOIR LIFE

(1) RESERVOIR	(2) NORMAL RESERVOIR LEVEL M ABOVE M.S.L.	(3) TOTAL VOLUME $m^3 \times 10^9$	(4) SUSPENDED-SEDIMENT LOAD t/yr	(5) GRAIN SIZE DISTRIBUTION PERCENT			(6) DENSITIES OF DEPOSITED SEDIMENTS AFTER 1 YR kg/m^3			(7)[2] VOLUME OF DEPOSITED SEDIMENT AFTER 1 YEAR $\frac{(4)\times(5)\times1000}{(6)}$ $m^3 \times 10^6$				(8) BEDLOAD		(9) TOTAL (7d)+(8b) $m^3 \times 10^6$	(10) LIFE (3)/(9) YEARS
				SAND .062 TO 2 mm	SILT .004 TO .062 mm	CLAY <.004 mm	SAND	SILT	CLAY	SAND (a)	SILT (b)	CLAY (c)	TOTAL (d)	t/yr (a)	$m^3 \times 10^6$/yr $m^3 \times 10^6$/y (b)		
STIKINE SITE Z	794.3 NORMAL MAX 749.0 NORMAL MIN	7.150 2.942	3,737,000	48	37	15	1488	1131	736	1.205	1.223	0.762	3.191	-[3]	-	3.191	2200 900
MORE CREEK	528.1 NORMAL MAX 482.8 NORMAL MIN	2.083 0.672	991,000	27	44	29	1488	1131	736	0.180	0.386	0.391	0.957	508,000	0.318	1.275[1] 0.957	1600 700
FORREST KERR	565.5 NORMAL MAX	0.012	253,000	19	45	36	1488	1131	736	0.032	0.101	0.124	0.257	-[3]	-	0.257	47
ISKUT CANYON	347.1 NORMAL MAX 312.0 NORMAL MIN	1.314 0.355	7,787,000	38	39	23	1488	1131	736	1.989	2.685	2.433	7.107	113,000	0.071	7.178 7.107	180 50

1 BEDLOAD IS ASSUMED TO SETTLE ONLY IN LIVE STORAGE

2 RESERVOIR TRAP EFFICIENCY IS ASSUMED TO BE 100% FOR ALL MATERIAL

3 BEDLOAD NOT MEASURED, BUT MAY BE CONSIDERABLE


INSET
Match line, see Inset
Match line
131°
N
CASSIAR
MOUNTAINS
DEASE LAKE
37
To Alaska Highway 246 km
230
GRAND CANYON OF THE STIKINE
SITE Z PROJECT
TANZILLA PROJECT
250
STIKINE RIVER
275
58°
180
TELEGRAPH CREEK
STIKINE PLATEAU
ISKUT VILLAGE
SPATSIZI PLATEAU
BOUNDARY RANGES
STIKINE RIVER
SPECTRUM RANGE
LOWER STIKINE TEST REACH
KLAPPAN RANGE
SKEENA MOUNTAINS
MORE CREEK TEST REACH
MORE CREEK PROJECT
125
BOB QUINN LAKE HIGHWAY CAMP
FORREST KERR DIVERSION DAM
UPPER ISKUT TEST REACH
BOB QUINN LAKE ECOLOGICAL RESERVE
ISKUT RIVER
LOWER ISKUT TEST REACH
ISKUT CANYON PROJECT
MITKOF ISLAND
ZAREMBO
B.C. Railway Dease Lake extension (not completed)
End of track
To Stewart 106 km
To Terrace 304 km
57°
132°
131°
130°
129°
KEY PLAN
YUKON
WATSON LAKE
CASSIAR
FORT NELSON
U.S.A.
STIKINE
STEWART
FORT ST JOHN
PRINCE RUPERT
KITWANGA
TERRACE
PRINCE GEORGE
ALBERTA
BRITISH COLUMBIA
PACIFIC OCEAN
VANCOUVER ISLAND
VANCOUVER
U.S.A.
LEGEND:
TOWN OR SETTLEMENT
PROJECT SITE
DISTANCE IN Km ALONG STIKINE RIVER FROM ALASKA BORDER AND ALONG ISKUT RIVER FROM CONFLUENCE WITH THE STIKINE RIVER
HIGHWAY
Scale: 10 0 10 20 30 40 Kilometres

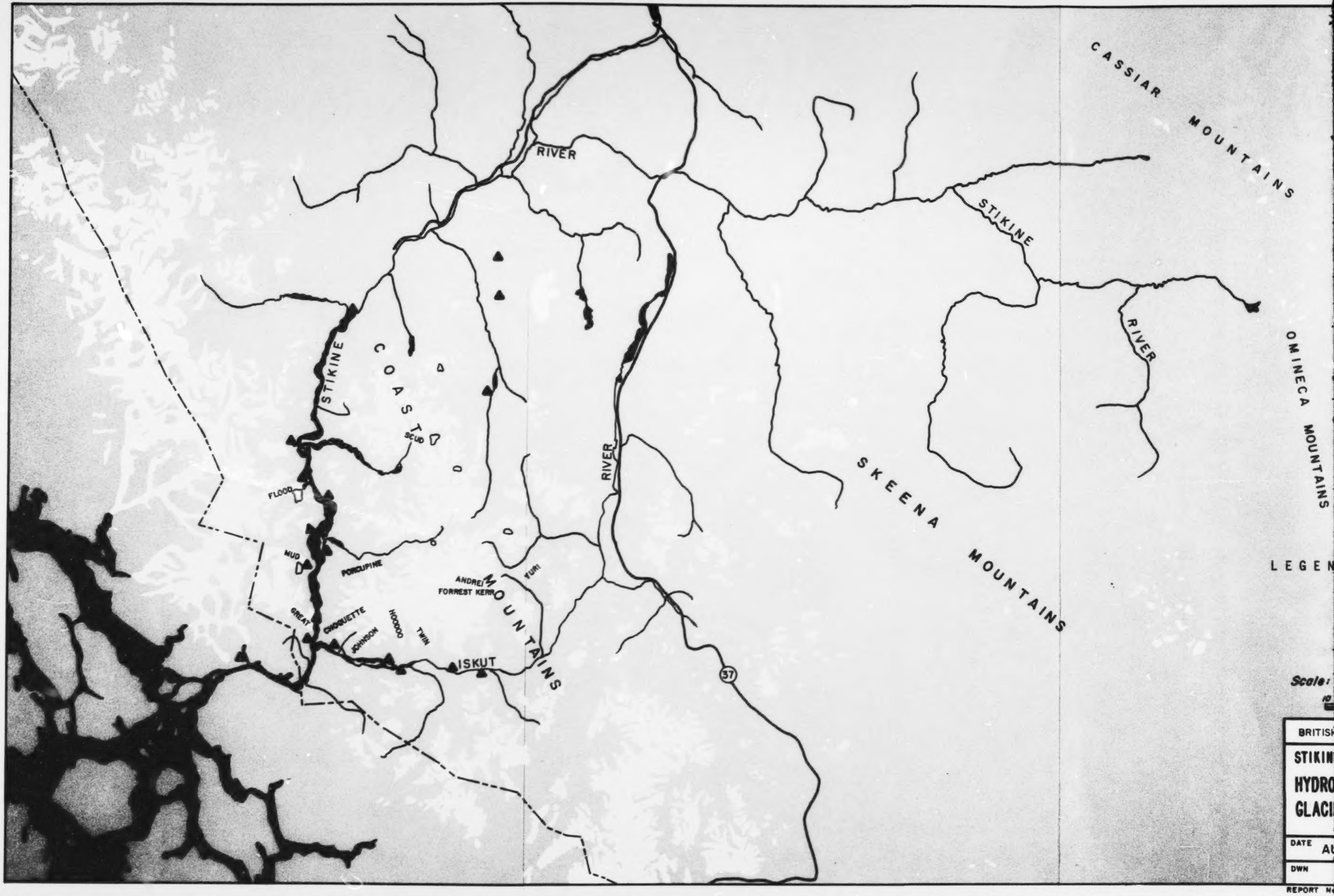
BRITISH COLUMBIA HYDRO AND POWER AUTHORITY

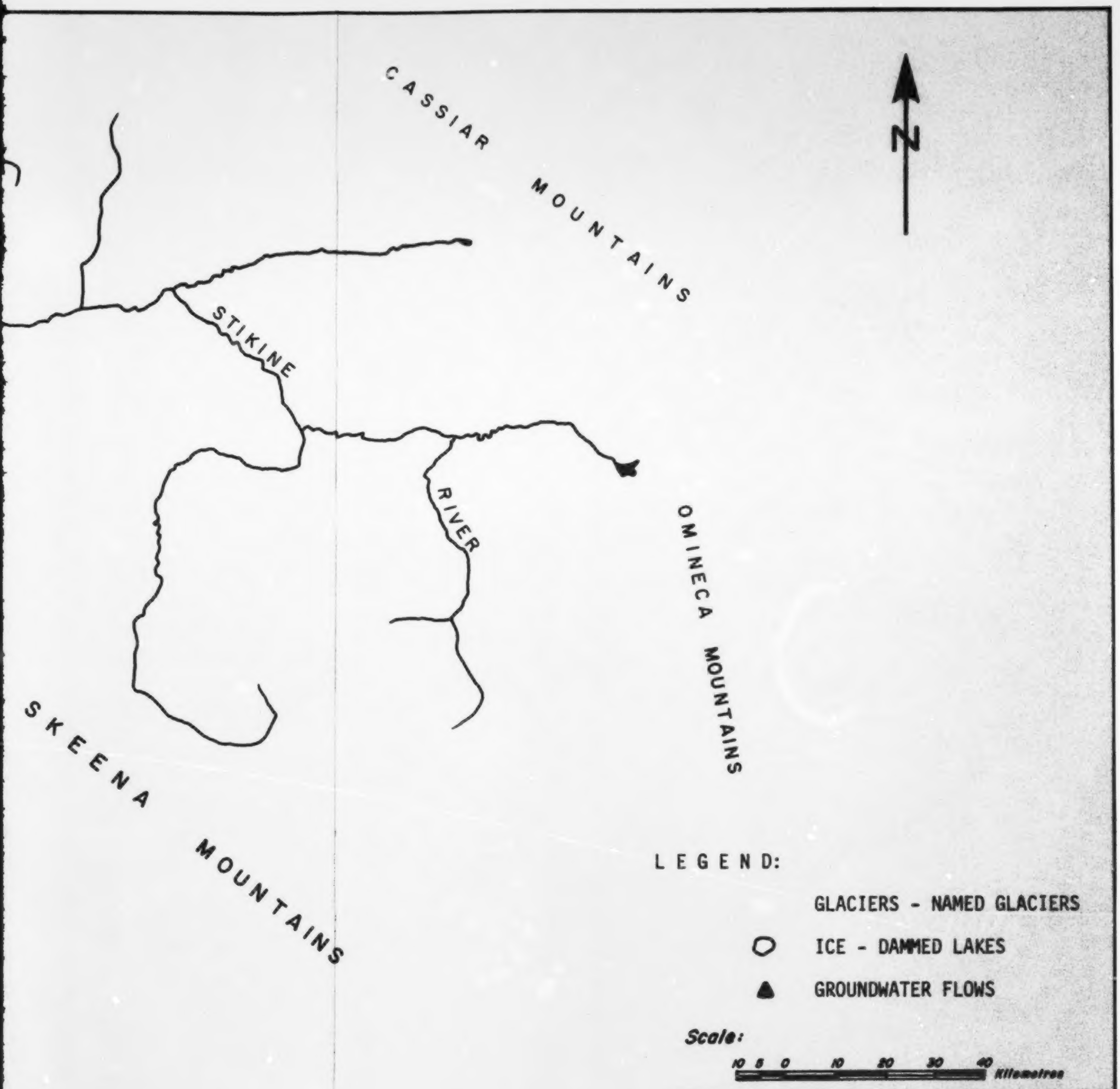
STIKINE - ISKUT FEASIBILITY STUDY

HYDROLOGY, RIVER REGIME & MORPHOLOGY STUDY AREA

DATE	AUG 1980	PLATE 2-1	R
DWN	K L	DWG No.	915-C14-D87

REPORT No. H-1110


CASSIAR MOUNTAINS
RIVER
STIKINE
STIKINE
RIVER
COAST
MOUNTAINS
SCUD
FLOOD
MUD
PORCUPINE
GREAT
CHOQUETTE
JOHNSON
HOODOO
TWIN
ANDREI
FORREST KERR
YURI
ISKUT
RIVER
37
SKEENA MOUNTAINS
OMINECA MOUNTAINS
LEGEN
Scale:
BRITISH
STIKIN
HYDRO
GLACI
DATE
DWN
REPORT N


CASSIAR MOUNTAINS
N
STIKINE
RIVER
OMINECA MOUNTAINS
SKEENA MOUNTAINS
LEGEND:
GLACIERS - NAMED GLACIERS
○ ICE - DAMMED LAKES
▲ GROUNDWATER FLOWS
Scale:
10 5 0 10 20 30 40 Kilometres

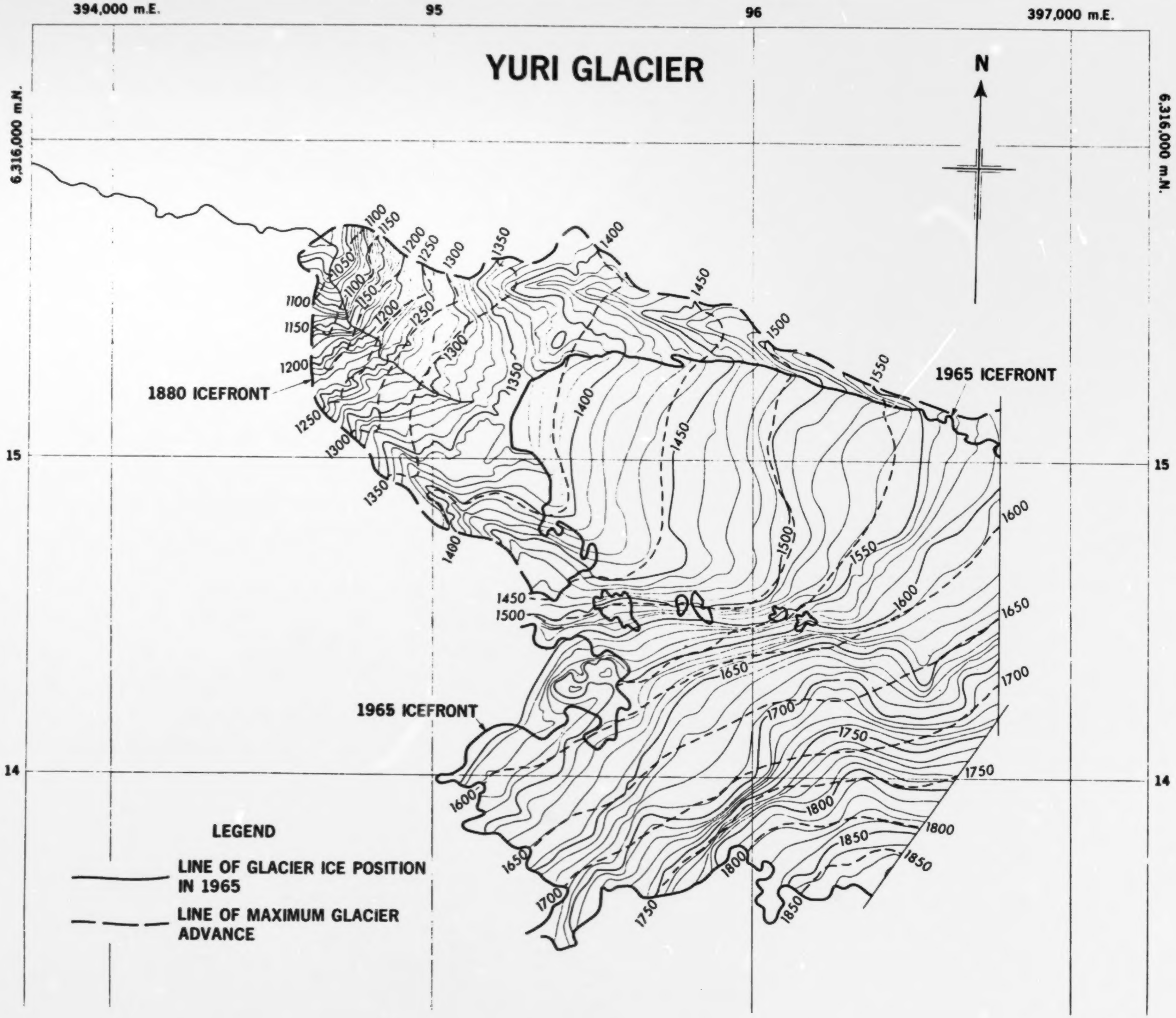
BRITISH COLUMBIA HYDRO AND POWER AUTHORITY

STIKINE - ISKUT FEASIBILITY STUDY

HYDROLOGY, RIVER REGIME & MORPHOLOGY
GLACIER LOCATION

DATE AUG 1980	PLATE 2 - 2
DWN K.L.	DWG. No 915 - C14 - B88

REPORT No H-1110


394,000 m.E.
95
96
397,000 m.E.
YURI GLACIER
N
6,316,000 m.N.
6,316,000 m.N.
15
15
14
14
1880 ICEFRONT
1965 ICEFRONT
1965 ICEFRONT
1050
1100
1150
1200
1250
1300
1350
1400
1450
1500
1550
1600
1650
1700
1750
1800
1850
LEGEND
LINE OF GLACIER ICE POSITION IN 1965
LINE OF MAXIMUM GLACIER ADVANCE

NOTE:

FOR GLACIER LOCATION SEE PLATE 2-2

Scale: 0 — *1000 Metres*

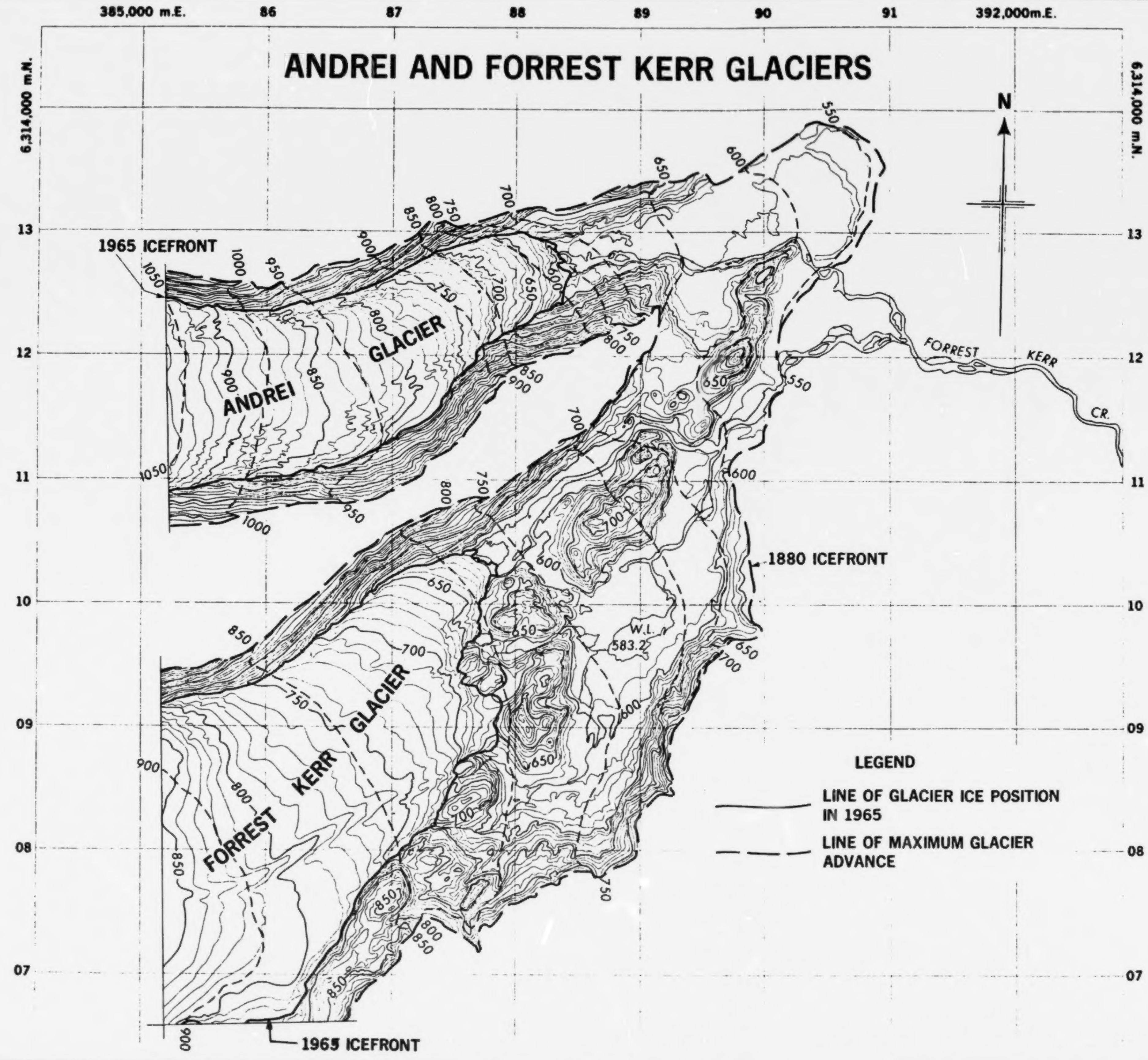
BRITISH COLUMBIA HYDRO AND POWER AUTHORITY

STIKINE - ISKUT FEASIBILITY STUDY
HYDROLOGY, RIVER REGIME & MORPHOLOGY
PLAN
YURI GLACIER

DATE AUG 1980	**PLATE 2-3**
DWN SMD	DWG. No 915 - C14 - B89

REPORT No. H-1110

ANDREI AND FORREST KERR GLACIERS


385,000 m.E.
86
87
88
89
90
91
392,000m.E.
6,314,000 m.N.
13
12
11
10
09
08
07
N
1965 ICEFRONT
ANDREI GLACIER
FORREST KERR GLACIER
FORREST KERR CR.
1880 ICEFRONT
W.L. 583.2
1965 ICEFRONT
550
600
650
700
750
800
850
900
950
1000
1050

LEGEND

———	LINE OF GLACIER ICE POSITION IN 1965
— — —	LINE OF MAXIMUM GLACIER ADVANCE

NOTE:

FOR GLACIER LOCATION SEE PLATE 2-2.

Scale:

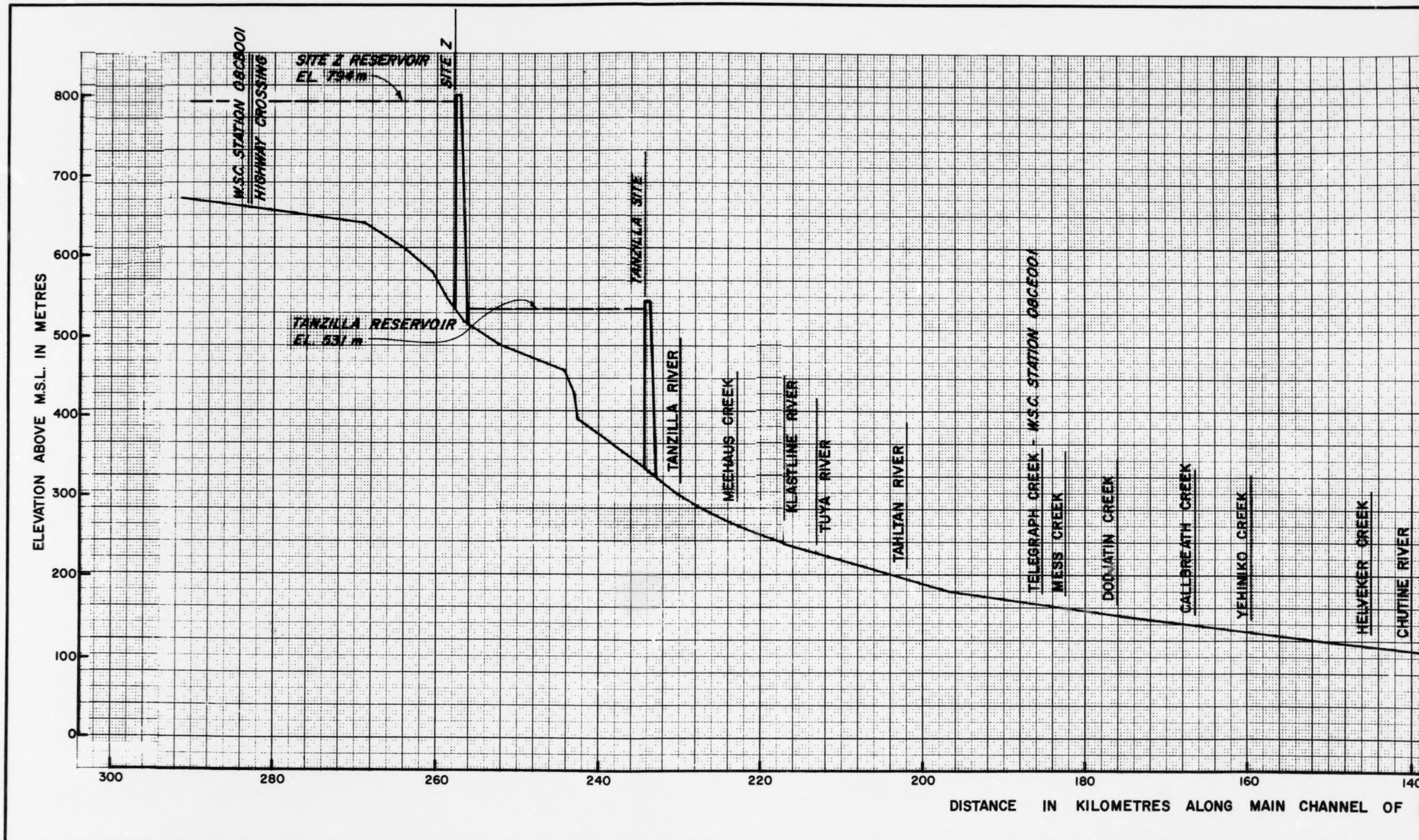
1000 0 1000 Metres

BRITISH COLUMBIA HYDRO AND POWER AUTHORITY

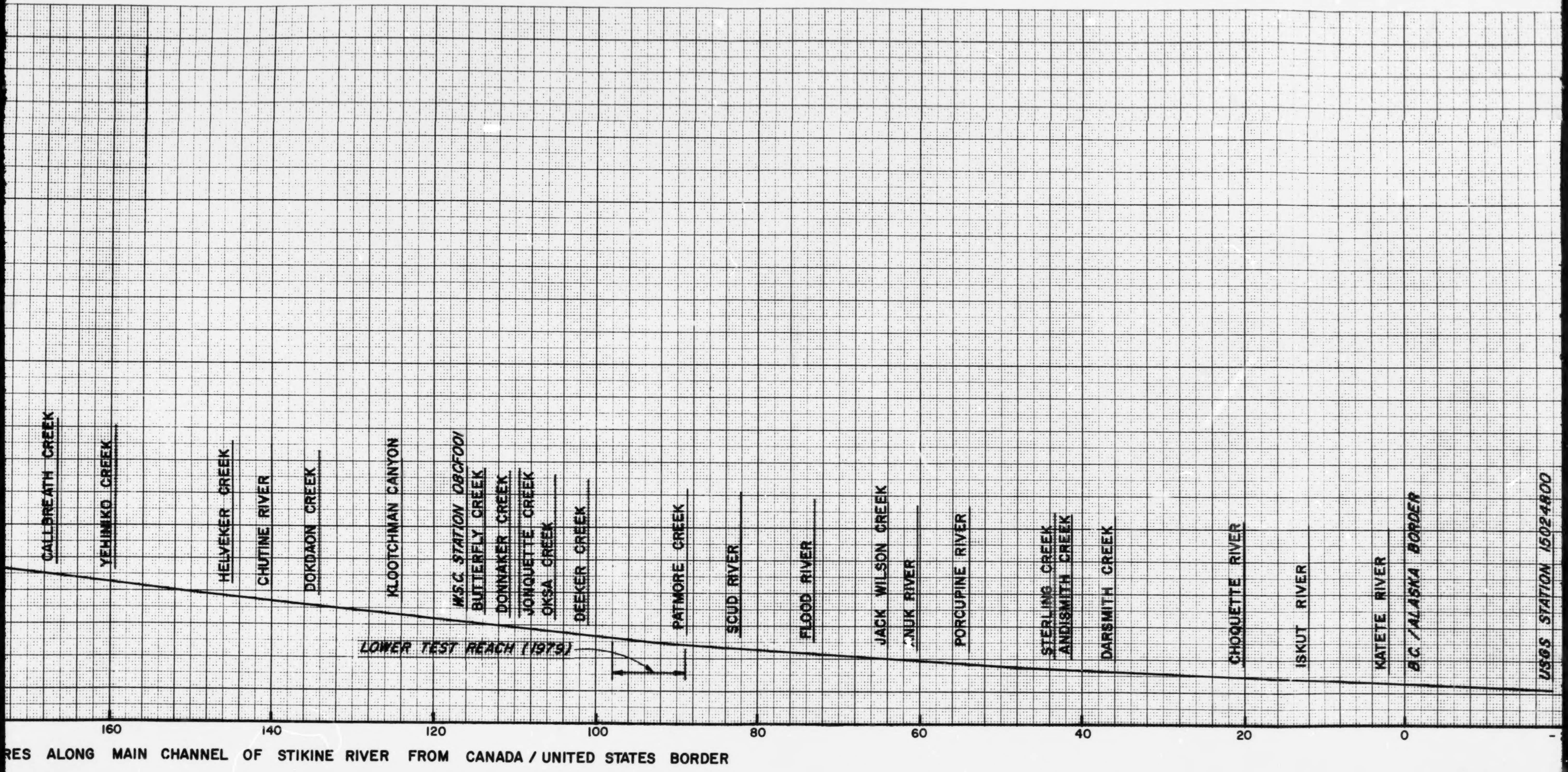
STIKINE – ISKUT FEASIBILITY STUDY
HYDROLOGY, RIVER REGIME & MORPHOLOGY
PLAN
ANDREI AND FORREST KERR GLACIERS

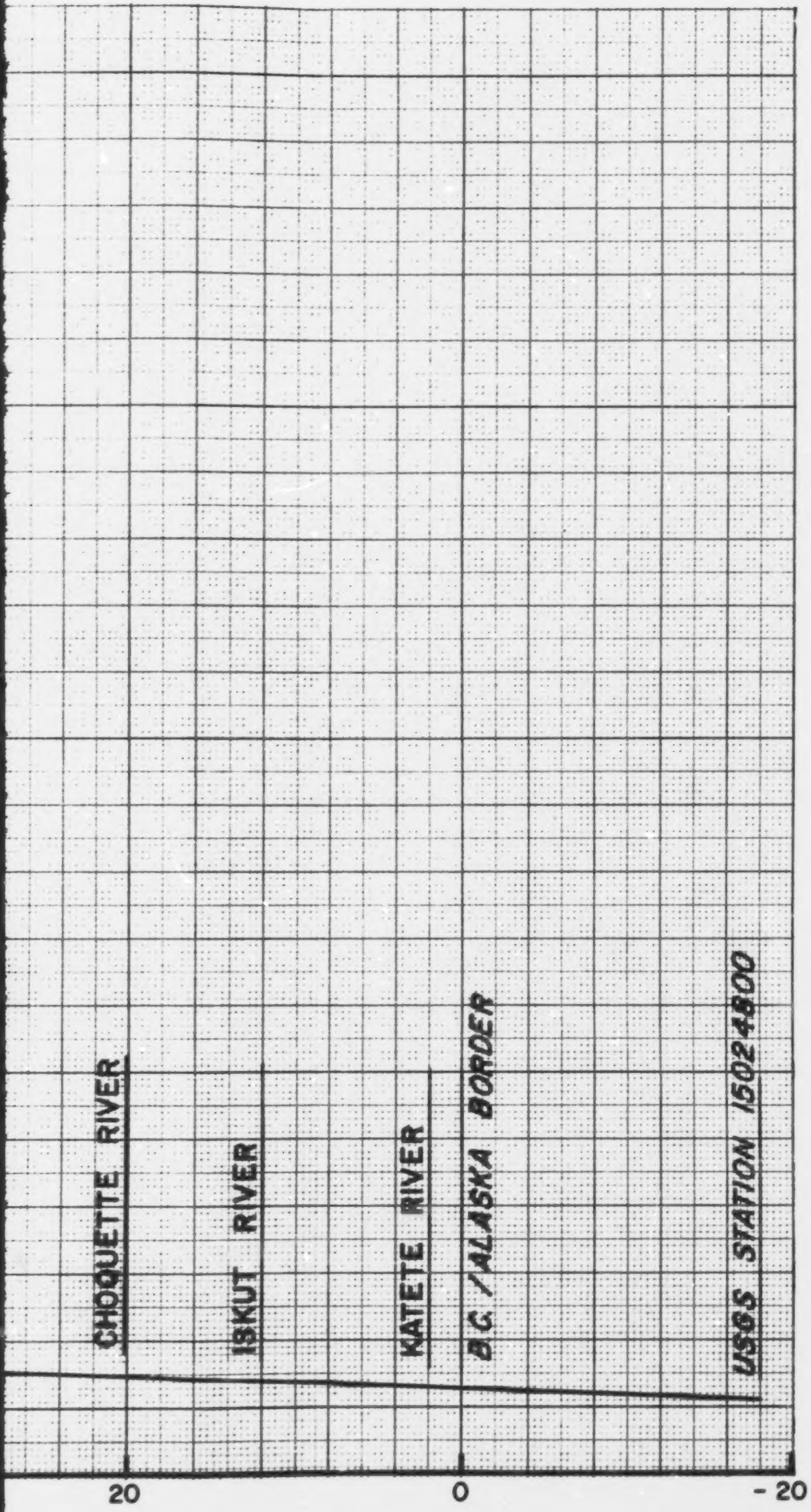
DATE AUG 1980	PLATE 2-4
DWN SMD	DWG. No. 915-C14-B90

REPORT No H-1110



ELEVATION ABOVE M.S.L. IN METRES
800
700
600
500
400
300
200
100
0
300
280
260
240
220
200
180
160
140
DISTANCE IN KILOMETRES ALONG MAIN CHANNEL OF
W.S.C. STATION 08CB001
HIGHWAY CROSSING
SITE Z RESERVOIR
EL. 794 m
SITE Z
TANZILLA RESERVOIR
EL. 531 m
TANZILLA SITE
TANZILLA RIVER
MEEHAUS CREEK
KLASTLINE RIVER
TUYA RIVER
TAHLTAN RIVER
TELEGRAPH CREEK - W.S.C. STATION 08CE001
MESS CREEK
DODJATIN CREEK
CALLBREATH CREEK
YEHINIKO CREEK
HELVEKER CREEK
CHUTINE RIVER


CALLBREATH CREEK
YEHINIKO CREEK
HELVEKER CREEK
CHUTINE RIVER
DOKDAON CREEK
KLOOTCHMAN CANYON
W.S.C. STATION 08CF001
BUTTERFLY CREEK
DONNAKER CREEK
JONQUETTE CREEK
OKSA CREEK
DEEKER CREEK
LOWER TEST REACH (1979)
PATMORE CREEK
SCUD RIVER
FLOOD RIVER
JACK WILSON CREEK
ANUK RIVER
PORCUPINE RIVER
STERLING CREEK
ANDISMITH CREEK
DARSMITH CREEK
CHOQUETTE RIVER
ISKUT RIVER
KATETE RIVER
B.C. /ALASKA BORDER
USGS STATION 15024800
160
140
120
100
80
60
40
20
0
-
RES ALONG MAIN CHANNEL OF STIKINE RIVER FROM CANADA / UNITED STATES BORDER



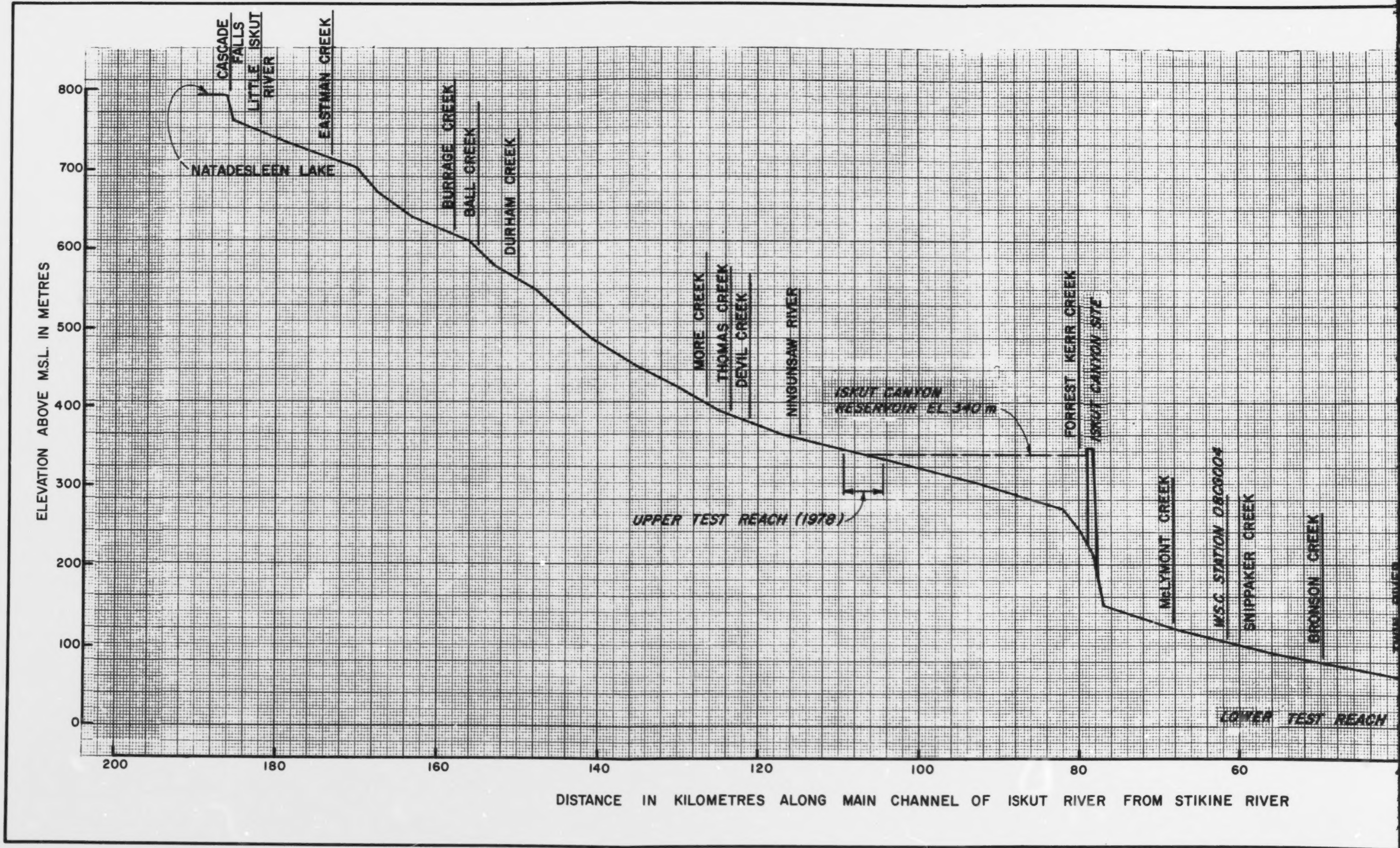
NOTE:

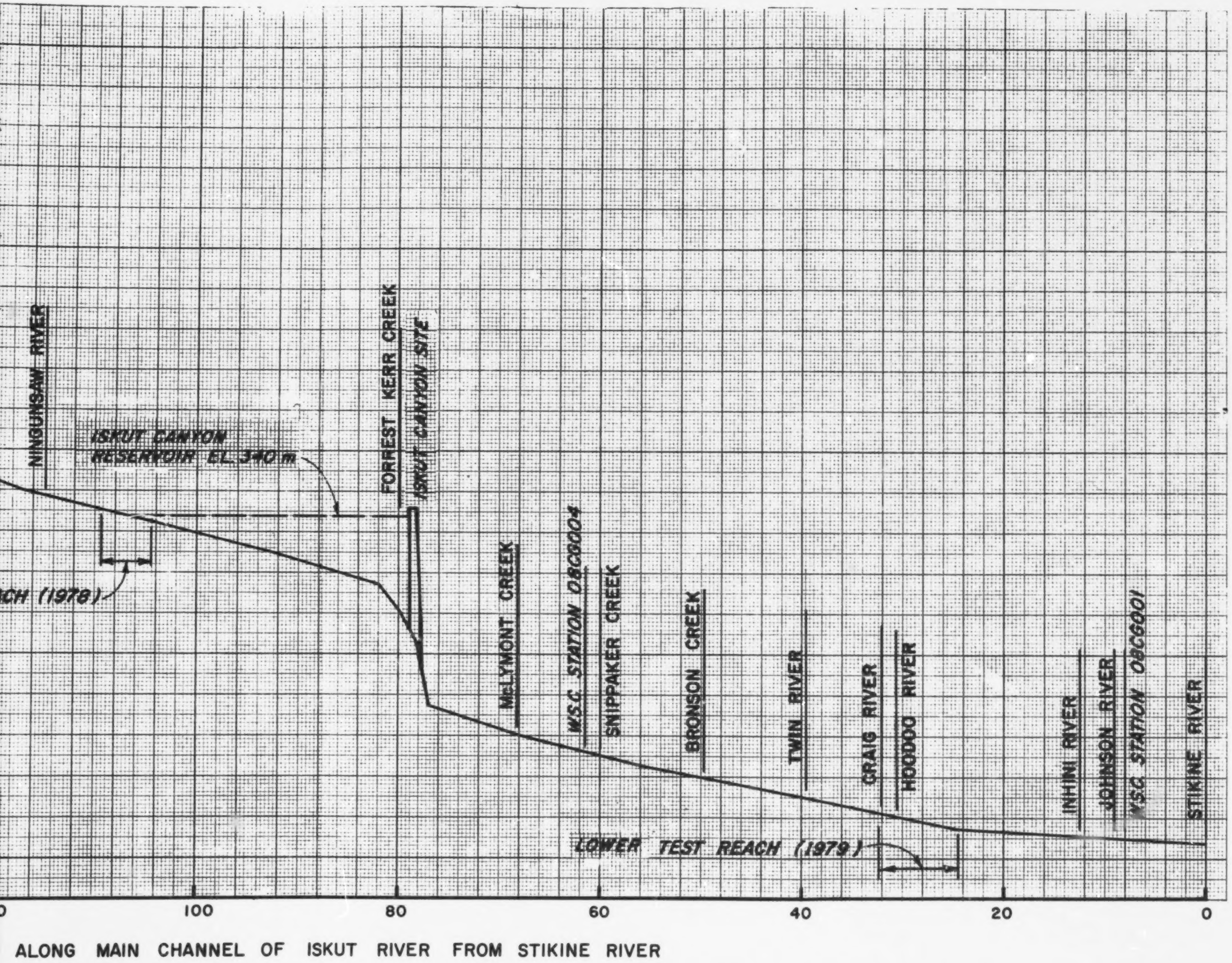
RIVER CHAINAGE AND ELEVATION WERE OBTAINED FROM 1:50,000 SCALE MAPS.

BRITISH COLUMBIA HYDRO AND POWER AUTHORITY

STIKINE - ISKUT FEASIBILITY STUDY
HYDROLOGY, RIVER REGIME & MORPHOLOGY
PROFILE
STIKINE RIVER

DATE AUG 1980	PLATE 2-5
DWN SMD	DWG. No 915 - C14 - U91


CASCADE FALLS
LITTLE ISKUT RIVER
EASTMAN CREEK
NATADESLEEN LAKE
BURRAGE CREEK
BALL CREEK
DURHAM CREEK
MORE CREEK
THOMAS CREEK
DEVIL CREEK
NINGUNSAW RIVER
ISKUT CANYON RESERVOIR EL. 340 m
FORREST KERR CREEK
ISKUT CANYON SITE
UPPER TEST REACH (1978)
McLYMONT CREEK
W.S.C. STATION 08CG004
SNIPPAKER CREEK
BRONSON CREEK
LOWER TEST REACH
ELEVATION ABOVE M.S.L. IN METRES
800
700
600
500
400
300
200
100
0
200
180
160
140
120
100
80
60
DISTANCE IN KILOMETRES ALONG MAIN CHANNEL OF ISKUT RIVER FROM STIKINE RIVER



NOTE:

RIVER CHAINAGE AND ELEVATION WERE OBTAINED FROM 1:50,000 SCALE MAPS.

BRITISH COLUMBIA HYDRO AND POWER AUTHORITY

STIKINE - ISKUT FEASIBILITY STUDY

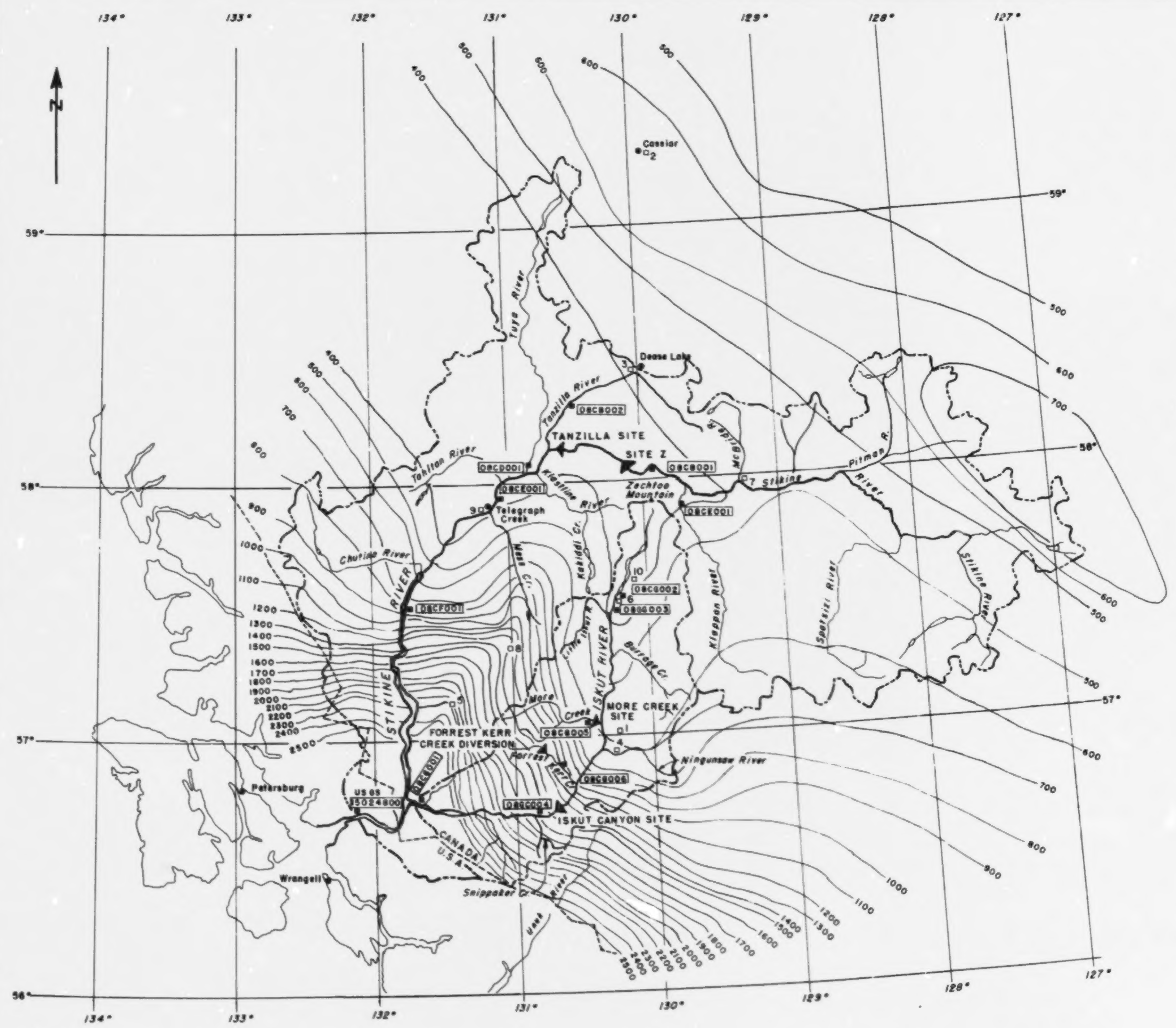
HYDROLOGY, RIVER REGIME & MORPHOLOGY

PROFILE

ISKUT RIVER

DATE AUG 1980	PLATE 2 - 6
DWN SMD	DWG. No. 915 - C14 - C92

REPORT No H-1110


N
134°
133°
132°
131°
130°
129°
128°
127°
59°
58°
57°
56°
Cassiar
Dease Lake
Tuya River
Tanzilla River
08CB002
TANZILLA SITE
SITE Z
08CB001
08CD001
08CE001
Tahltan River
Klastline River
Zechtoo Mountain
08CC001
Telegraph Creek
McBride R.
Stikine
Pitman R.
Chutine River
08CF001
STIKINE RIVER
Mess Cr.
Kakiddi Cr.
08CG002
08CG003
Little Iskut R.
ISKUT RIVER
Klappan River
Spatsizi River
Stikine River
Burrage Cr.
More Creek
MORE CREEK SITE
08CG005
FORREST KERR CREEK DIVERSION
Forrest Kerr Cr.
08CG006
Ningunsaw River
08CG001
08CG004
ISKUT CANYON SITE
US 65 15024800
Petersburg
Wrangell
CANADA
U.S.A.
Snippaker Cr.
Iskut River
Unuk River
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
2100
2200
2300
2400
2500

NOTE:

CLIMATOLOGICAL STATIONS USED IN PREPARING THE ISOHYETS ARE AS FOLLOWS: 1. BOB QUINN LK., 2. CASSIAR, 3. DEASE LK., 4. ECHO LK., 5. GALORE CR., 6. KINASKAN LK., 7. McBRIDE R., 8. SCHAFT CR., 9. TELEGRAPH CR., 10. TODAGIN RANCH

LEGEND

SITE ___	◀	PROPOSED DAM SITE
08CG005	■	WSC GAUGING STATION
	□	AES CLIMATOLOGICAL STATION
		TOWNS
⌒ 1200 ⌒		ISOHYETS IN MILLIMETRES
‿ - - ‿ - -		OUTLINE OF DRAINAGE AREA OF THE ISKUT AND STIKINE RIVER SYSTEMS

SUMMARY OF HYDROMETRIC STATIONS

STATION NO.	SYMBOL	STATION NAME
08CC001	■	KLAPPAN RIVER NEAR TELEGRAPH CREEK
08CB001	■	STIKINE RIVER ABOVE GRAND CANYON
08CD001	■	TUYA RIVER NEAR TELEGRAPH CREEK
08CE001	■	STIKINE RIVER AT TELEGRAPH CREEK
08CF001	■	STIKINE RIVER ABOVE BUTTERFLY CREEK
08CG001	■	ISKUT RIVER BELOW JOHNSON RIVER
08CG004	■	ISKUT RIVER ABOVE SNIPPAKER CREEK
08CG006	■	FORREST KERR CREEK ABOVE 460 m CONTOUR
08CG005	■	MORE CREEK NEAR THE MOUTH
08CG003	■	ISKUT RIVER AT OUTLET OF KINASKAN LAKE
15024800	■	STIKINE RIVER NEAR WRANGELL, ALASKA
	□ 1	CHUTINE RIVER BELOW WRIGGLE CREEK
	□ 2	CRAIG RIVER NEAR THE MOUTH

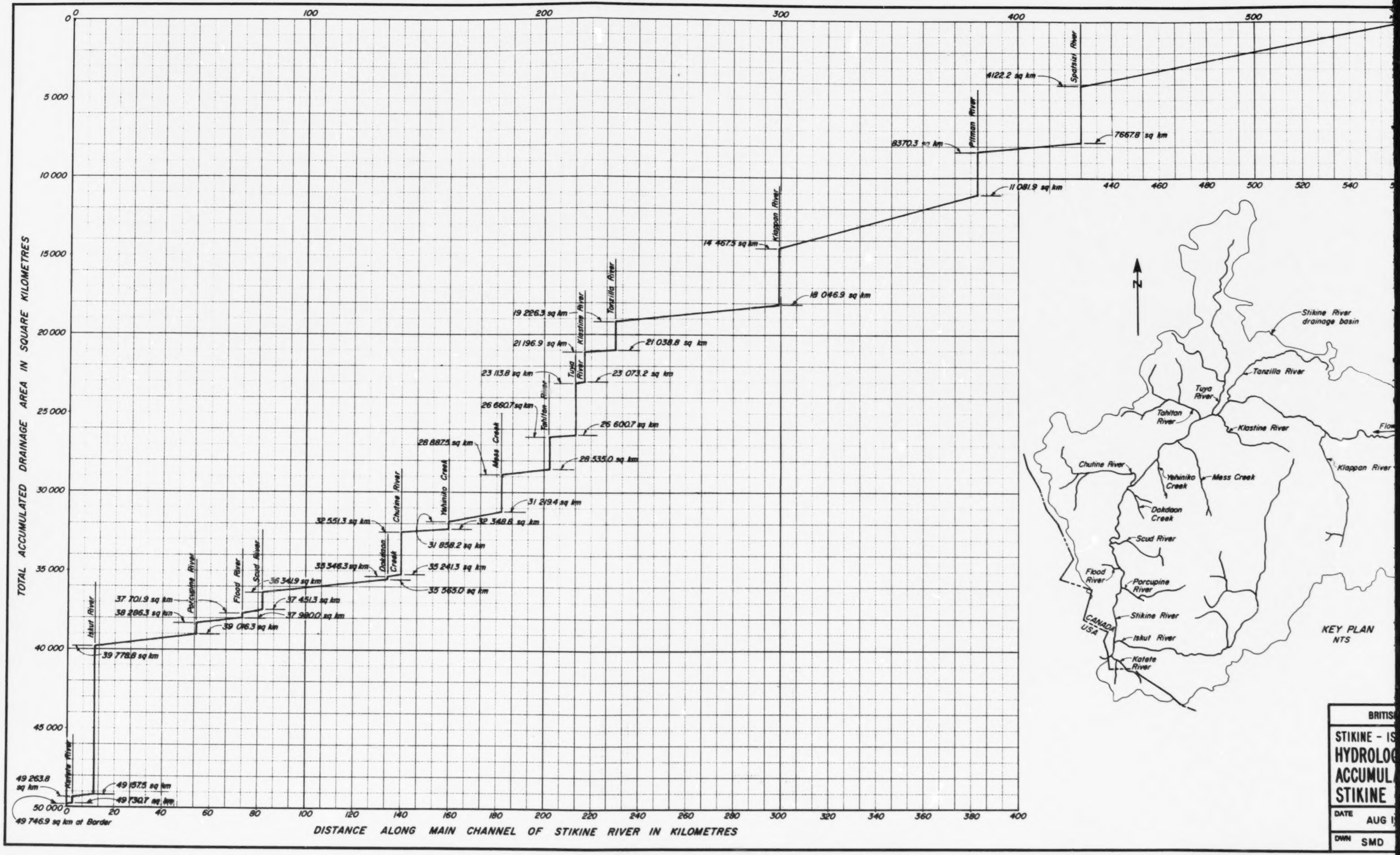
BRITISH COLUMBIA HYDRO AND POWER AUTHORITY

STIKINE - ISKUT FEASIBILITY STUDY

HYDROLOGY, RIVER REGIME & MORPHOLOGY ISOHYET MAP

DATE	AUG 1980	PLATE 2-7	R
DWN	K.L.	DWG No. 915-C14-D93	

REPORT No. H-1110

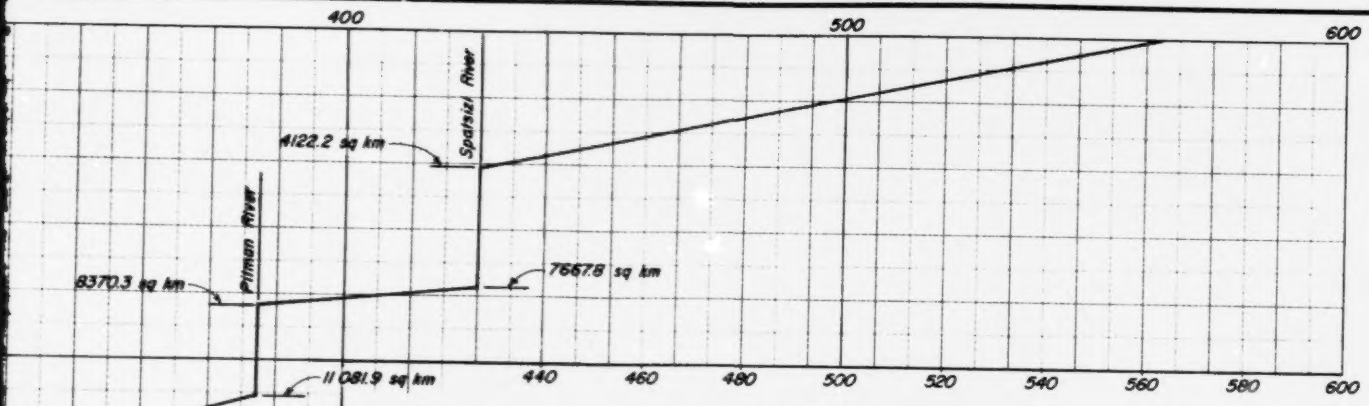


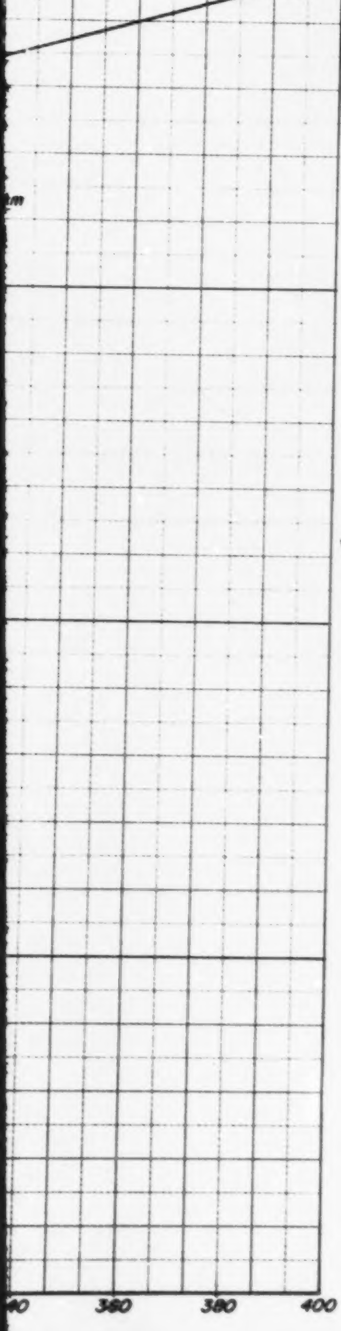
BRITIS

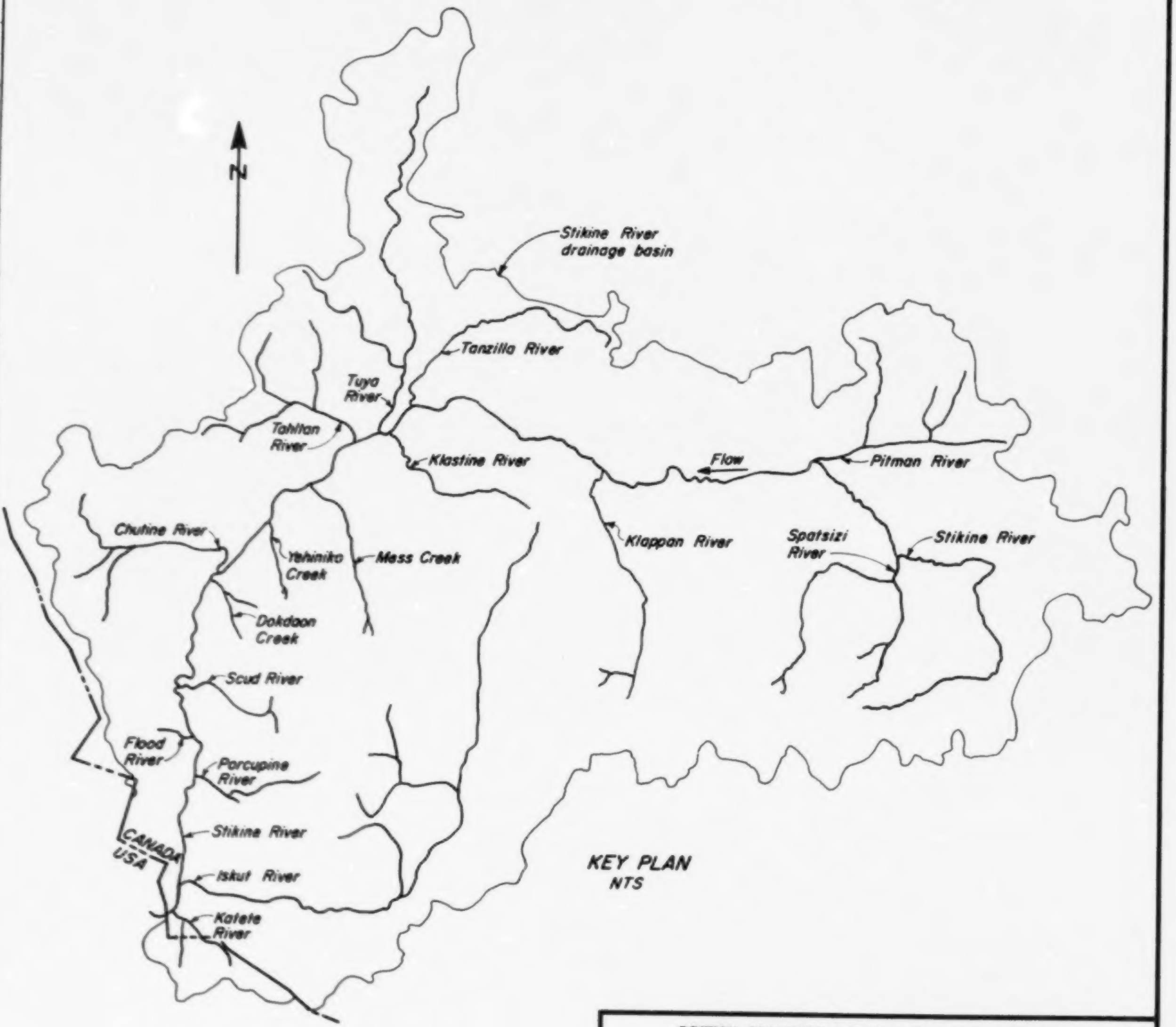
STIKINE - IS
HYDROLOG
ACCUMULA
STIKINE

DATE AUG I

DWN SMD



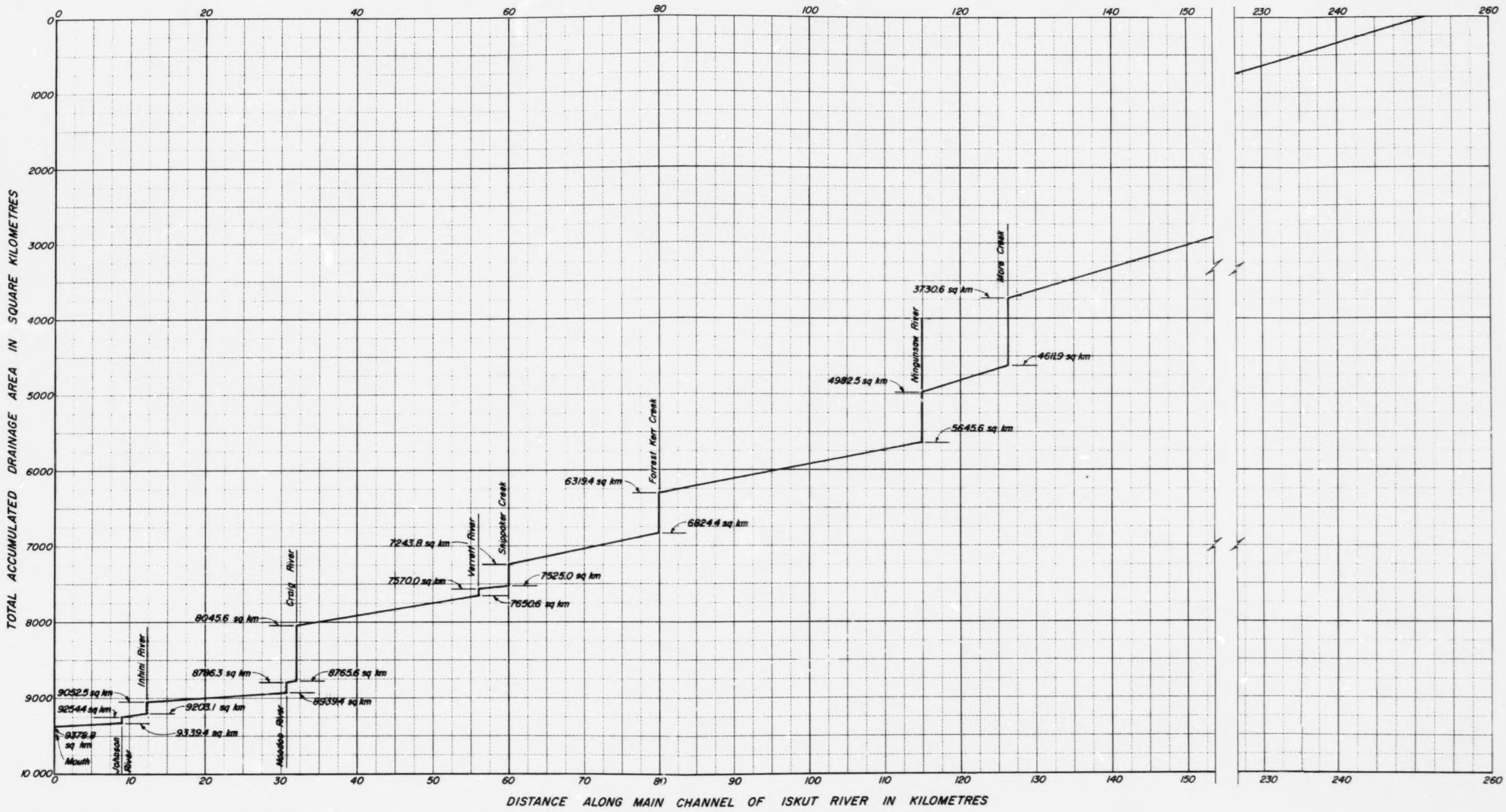


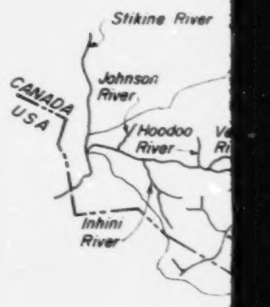

N
Stikine River drainage basin
Tanzilla River
Tuya River
Tahltan River
Klastine River
Flow
Pitman River
Chutine River
Yehiniko Creek
Mess Creek
Klappan River
Spatsizi River
Stikine River
Dokdaon Creek
Scud River
Flood River
Porcupine River
Stikine River
CANADA
USA
Iskut River
Katete River
KEY PLAN
NTS

BRITISH COLUMBIA HYDRO AND POWER AUTHORITY

STIKINE - ISKUT FEASIBILITY STUDY
HYDROLOGY, RIVER REGIME & MORPHOLOGY
ACCUMULATED DRAINAGE AREAS
STIKINE RIVER

DATE AUG 1980	PLATE 2 - 8	R
DWN SMD	DWG No. 915 - C14 - U94	



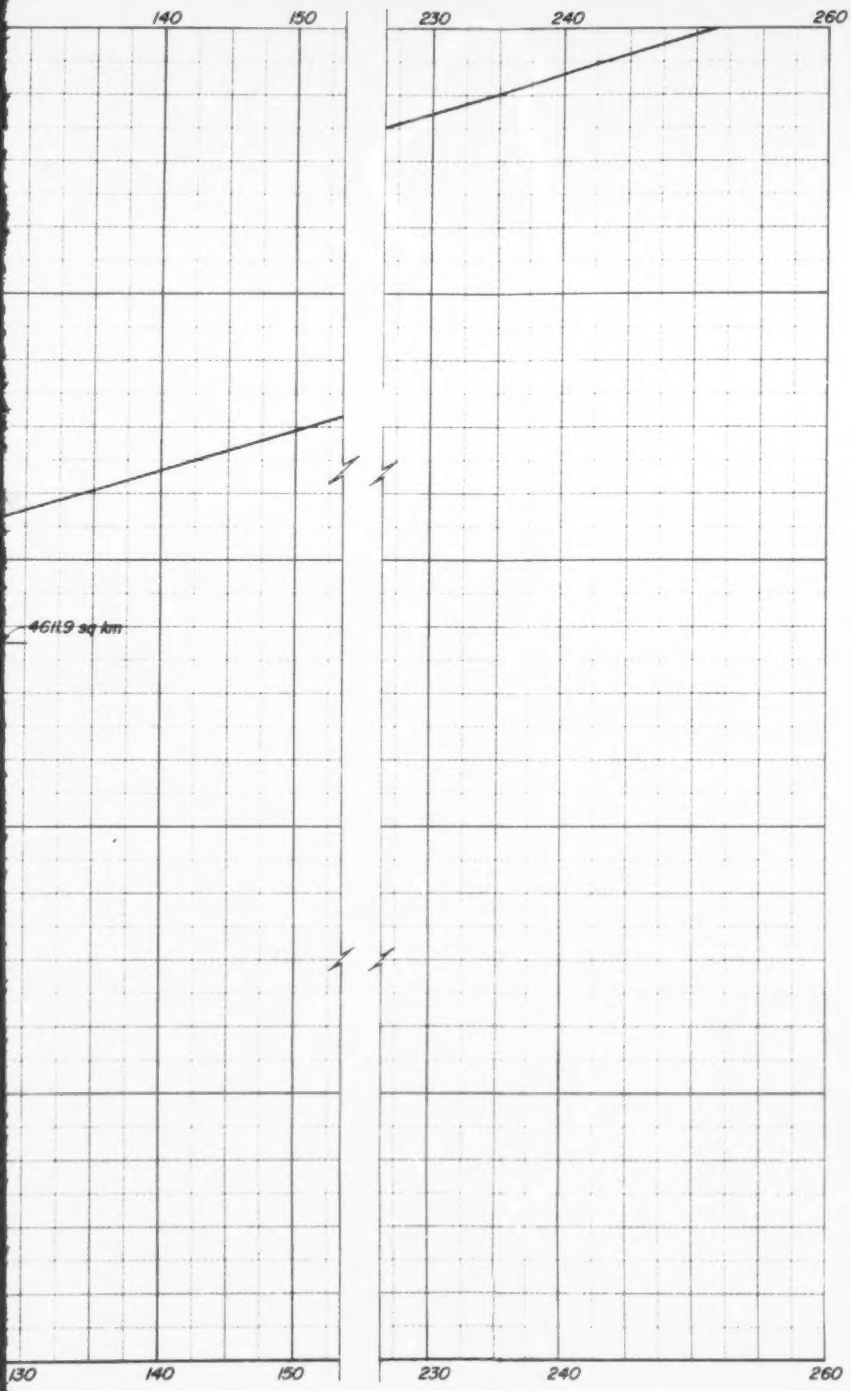

Stikine River
Johnson River
CANADA
USA
Hoodoo River
Ve
Ri
Inhini River

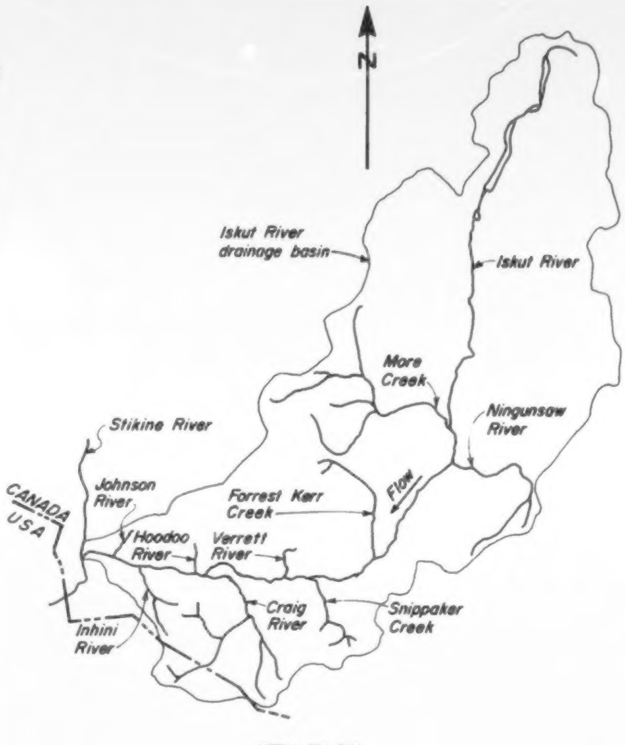
BRI

STIKINE –
HYDROL
ACCUMU
ISKUT

DATE AUG

DWN SMD



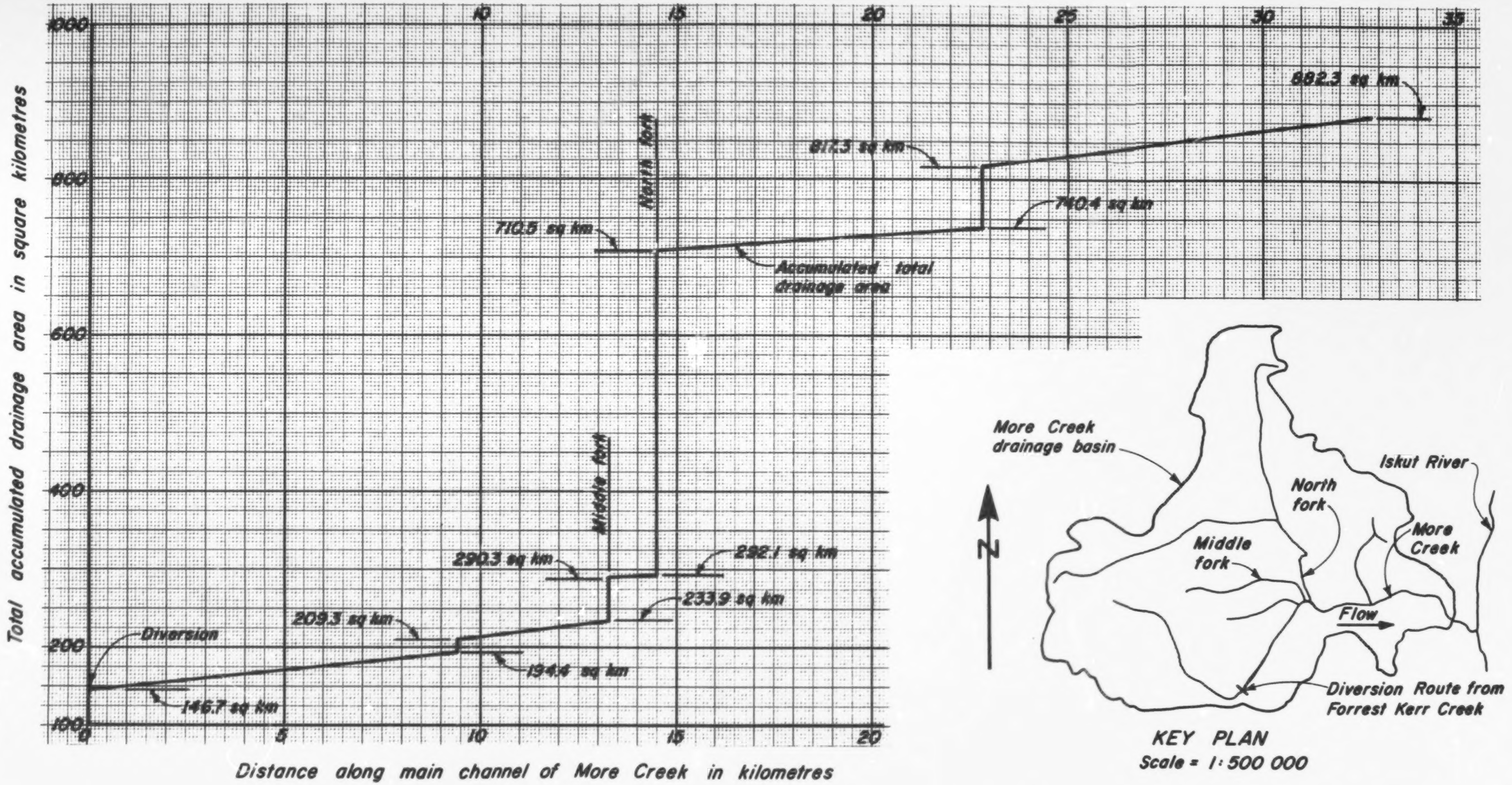

N
Iskut River drainage basin
Iskut River
More Creek
Ningunsaw River
Stikine River
Johnson River
CANADA
USA
Forrest Kerr Creek
Flow
Hoodoo River
Verrett River
Craig River
Snippaker Creek
Inhini River

KEY PLAN
NTS

BRITISH COLUMBIA HYDRO AND POWER AUTHORITY

STIKINE – ISKUT FEASIBILITY STUDY
HYDROLOGY, RIVER REGIME & MORPHOLOGY
ACCUMULATED DRAINAGE AREAS
ISKUT RIVER

DATE AUG 1980	PLATE 2 - 9	R
DWN SMD	DWG No. 915 - C14 - U95	

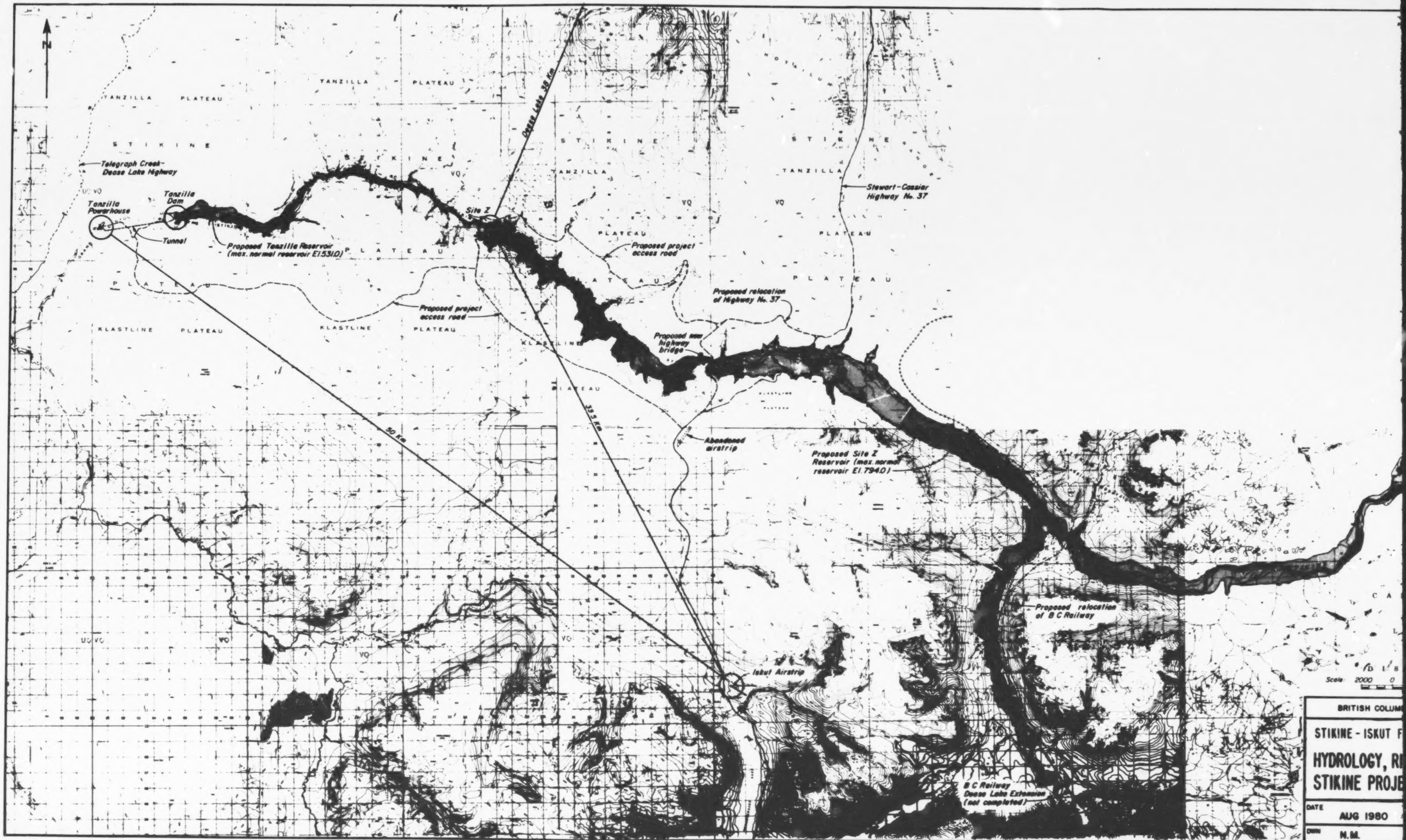


BRITISH COLUMBIA HYDRO AND POWER AUTHORITY

STIKINE - ISKUT FEASIBILITY STUDY
HYDROLOGY, RIVER REGIME & MORPHOLOGY
ACCUMULATED DRAINAGE AREAS
MORE CREEK

DATE AUG 1980	**PLATE 2 - 10**
DWN SMD	DWG. No 915 - C14 - B96

REPORT No H-1110


N
TANZILLA PLATEAU
STIKINE
Telegraph Creek-Dease Lake Highway
Tanzilla Powerhouse
Tanzilla Dam
Tunnel
Proposed Tanzilla Reservoir (max. normal reservoir El.531.0)
PLATEAU
KLASTLINE PLATEAU
Proposed project access road
Dease Lake 38 Km
Site Z
STIKINE
TANZILLA
VQ
PLATEAU
Proposed project access road
Stewart-Cassiar Highway No. 37
Proposed relocation of Highway No. 37
Proposed new highway bridge
KLASTLINE
PLATEAU
Abandoned airstrip
Proposed Site Z Reservoir (max. normal reservoir El.794.0)
50 Km
39.5 Km
Proposed relocation of B C Railway
Iskut Airstrip
B C Railway Dease Lake Extension (not completed)
Scale: 2000 0

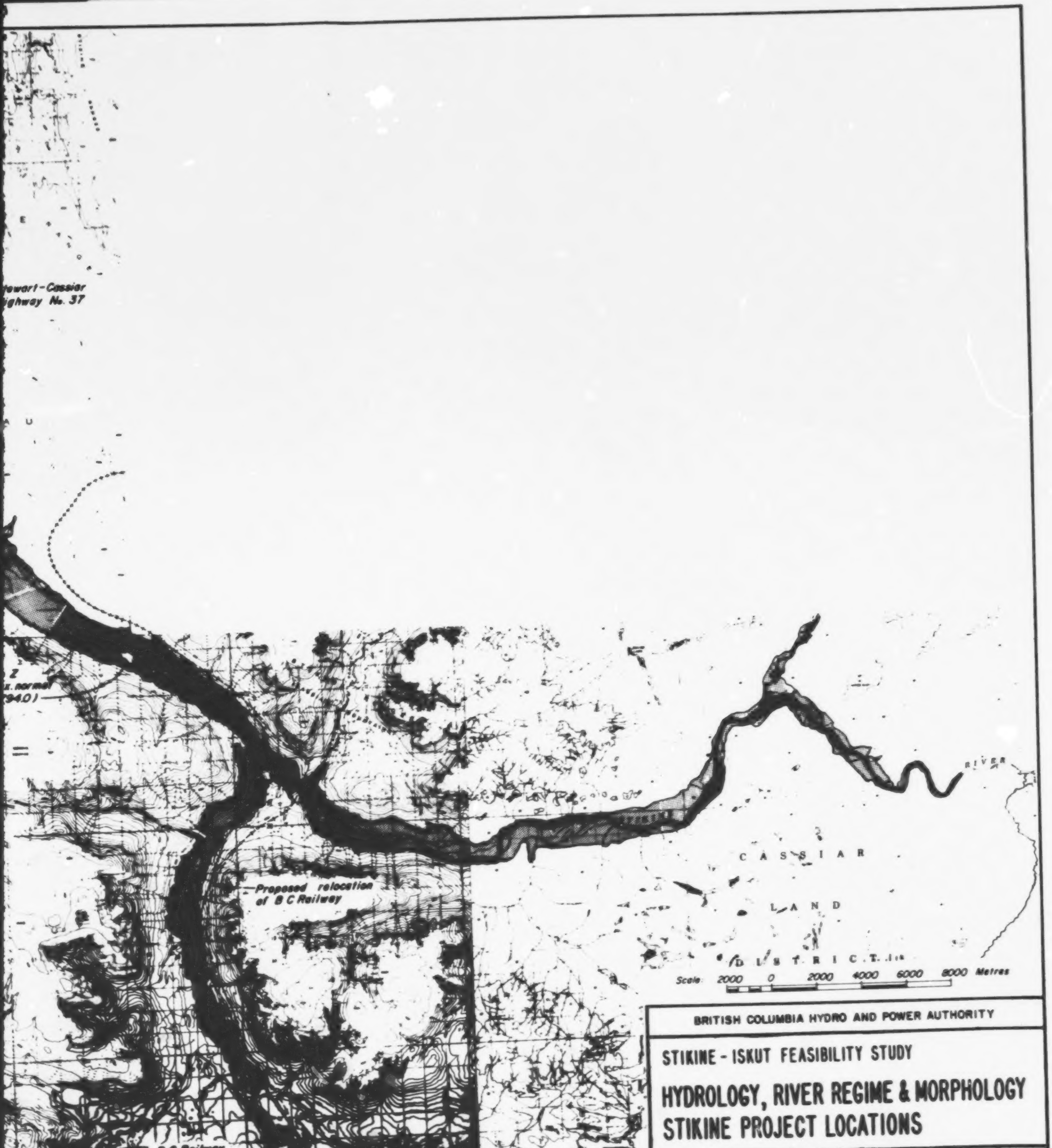
BRITISH COLUM

STIKINE - ISKUT F

HYDROLOGY, R
STIKINE PROJE

DATE AUG 1980

DWN N.M.

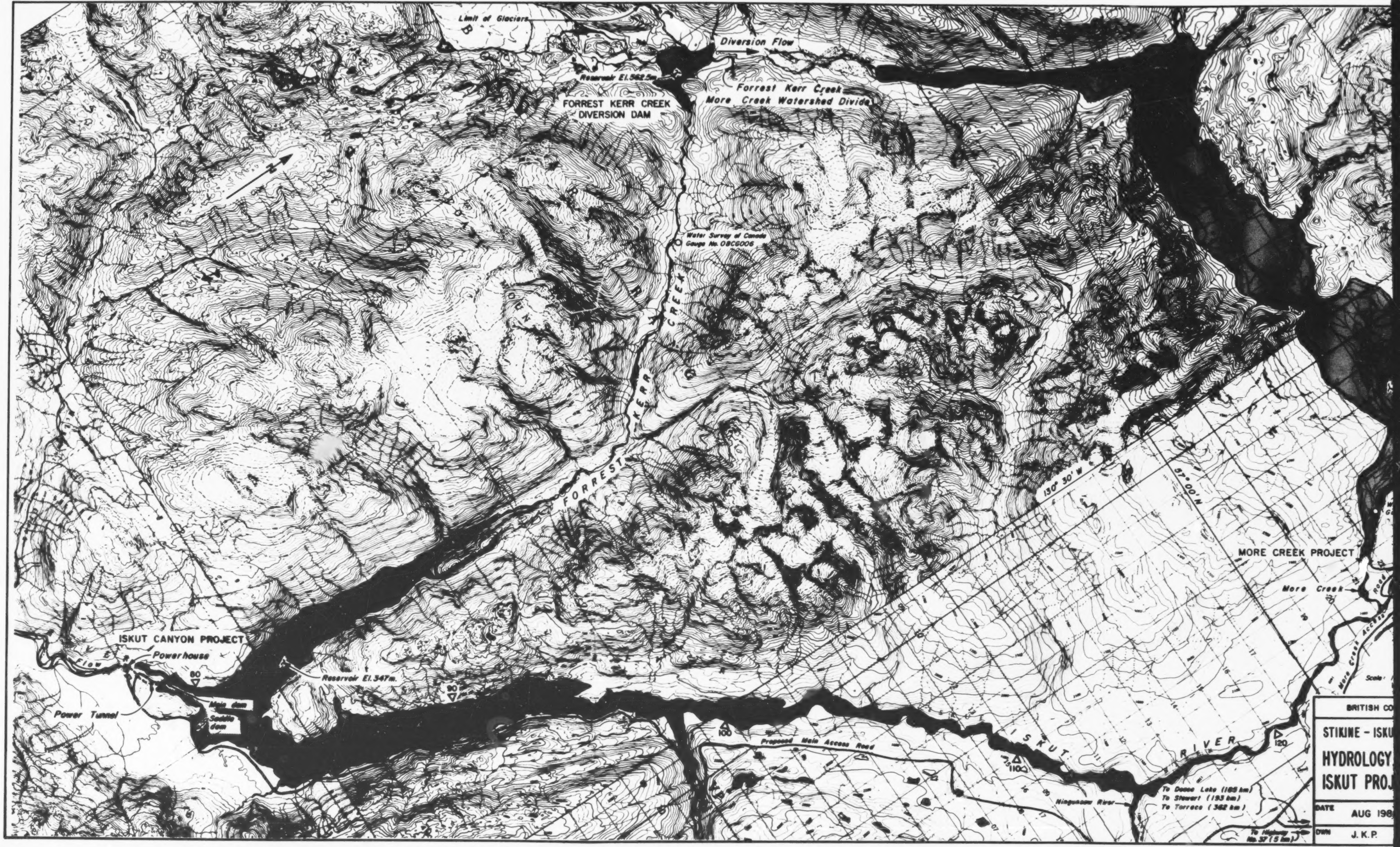

tewart-Cassiar
ighway No. 37
x. normal
940)
Proposed relocation of B C Railway
B C Railway Dease Lake Extension (not completed)
RIVER
CASSIAR LAND DISTRICT
Scale: 2000 0 2000 4000 6000 8000 Metres

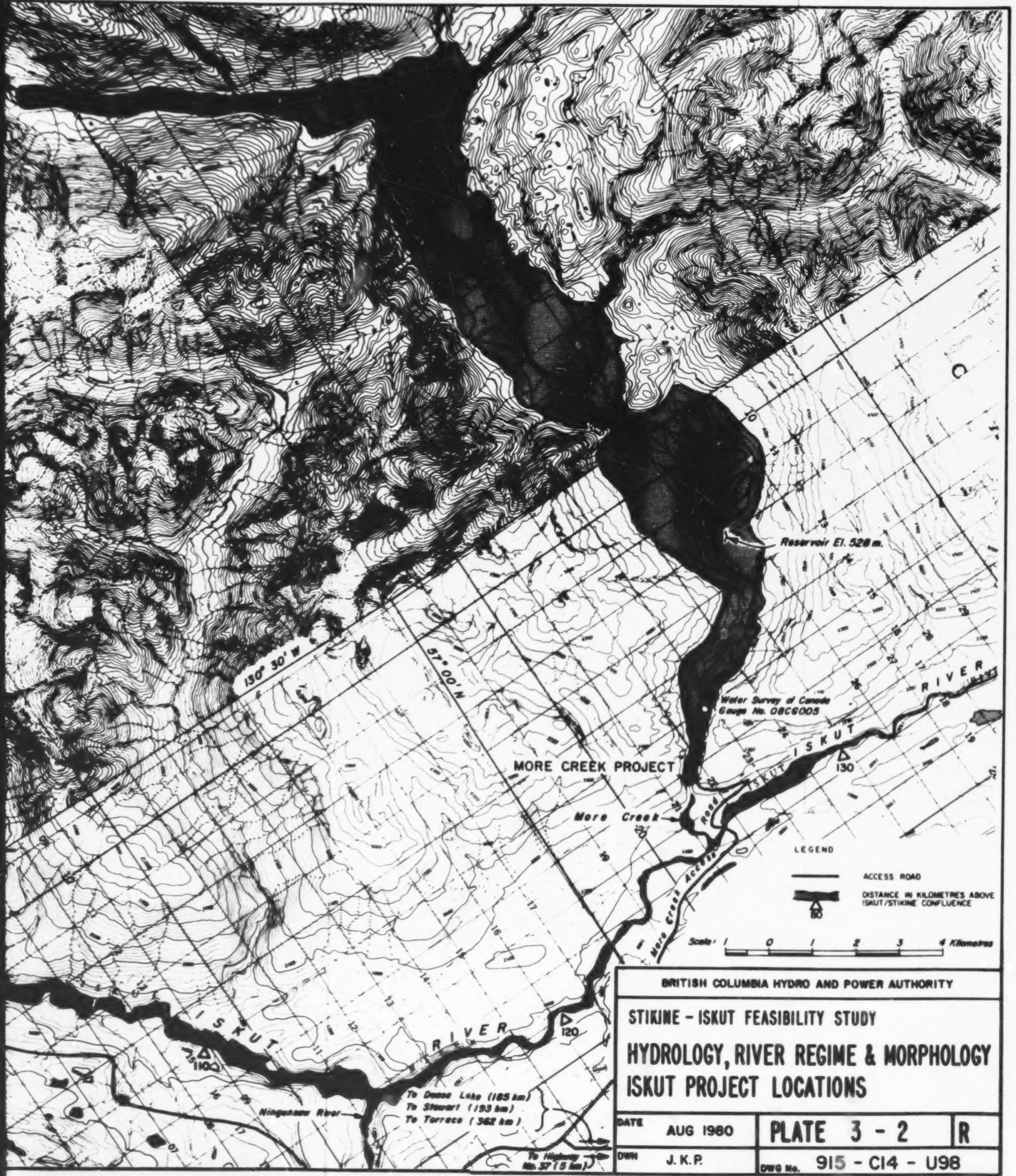
BRITISH COLUMBIA HYDRO AND POWER AUTHORITY

STIKINE - ISKUT FEASIBILITY STUDY

HYDROLOGY, RIVER REGIME & MORPHOLOGY
STIKINE PROJECT LOCATIONS

DATE AUG 1980	PLATE 3-1	R
DWN N.M.	DWG No. 915 - C14 - U97	


Limit of Glaciers
Diversion Flow
Reservoir El. 562.5m
FORREST KERR CREEK
DIVERSION DAM
Forrest Kerr Creek
More Creek Watershed Divide
Water Survey of Canada
Gauge No. 08CG006
FORREST KERR CREEK
130° 30' W
57° 00' N
MORE CREEK PROJECT
More Creek
ISKUT CANYON PROJECT
Powerhouse
Flow
80
Reservoir El. 347m.
Main dam
Saddle dam
Power Tunnel
90
100
Proposed Main Access Road
110
ISKUT RIVER
120
Ningunsaw River
To Dease Lake (165 km)
To Stewart (193 km)
To Terrace (362 km)
To Highway No. 37 (5 km)
Scale:
BRITISH CO
STIKINE - ISKU
HYDROLOGY
ISKUT PROJ
DATE
AUG 198
DWN
J.K.P.


130° 30' W
57° 00' N
Reservoir El. 528 m.
Water Survey of Canada
Gauge No. 08CG005
MORE CREEK PROJECT
More Creek
More Creek Access Road
ISKUT RIVER
ISKUT
130
120
110
Iskut River
Ningunsaw River
To Dease Lake (185 km)
To Stewart (193 km)
To Terrace (362 km)
To Highway No. 37 (5 km)
LEGEND
ACCESS ROAD
DISTANCE IN KILOMETRES ABOVE ISKUT/STIKINE CONFLUENCE
130
Scale: 1 0 1 2 3 4 Kilometres

BRITISH COLUMBIA HYDRO AND POWER AUTHORITY

STIKINE - ISKUT FEASIBILITY STUDY

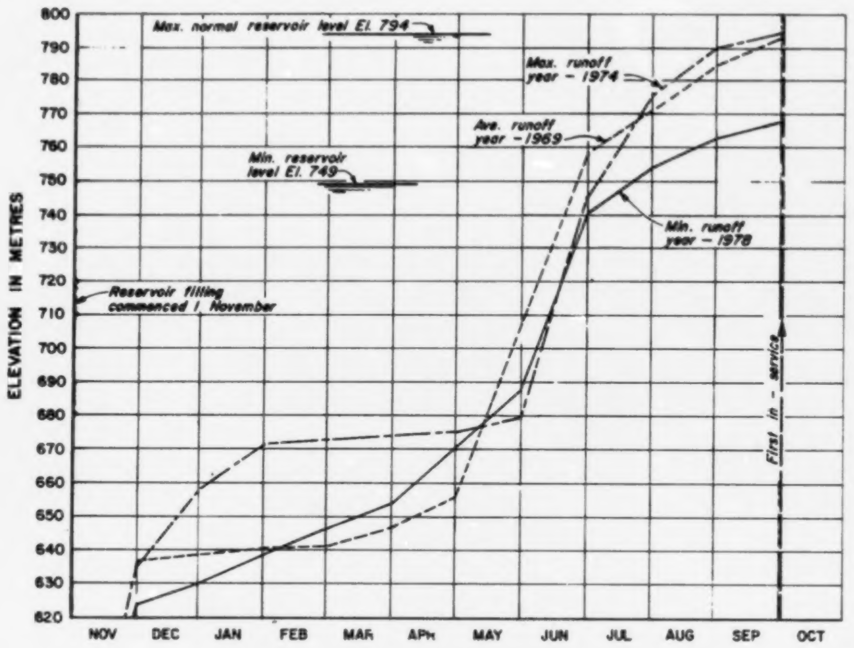
HYDROLOGY, RIVER REGIME & MORPHOLOGY
ISKUT PROJECT LOCATIONS

DATE AUG 1980

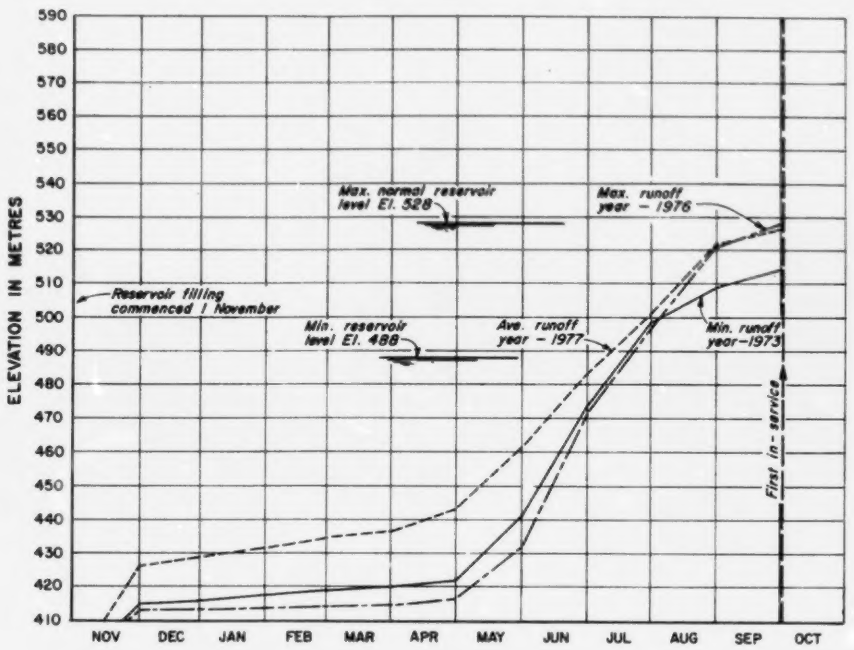
PLATE 3 - 2 R

DWN J. K. P.

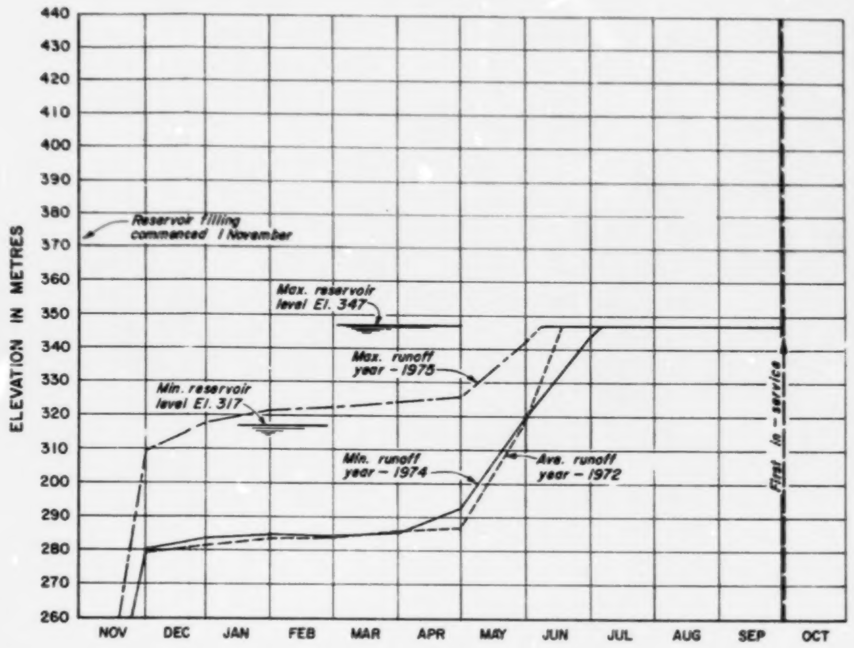
DWG No. 915 - C14 - U98



SITE Z PROJECT
RESERVOIR FILLING CURVES



MORE CREEK PROJECT
RESERVOIR FILLING CURVES



ISKUT CANYON PROJECT
RESERVOIR FILLING CURVES

NOTES:

1. RESERVOIR FILLING CRITERIA FOR ALL PROJECTS EXCEPT THE STIKINE TANZILLA PROJECT ASSUMED TO BE AS FOLLOWS:
    - RELEASES NOVEMBER TO MAY INCLUSIVE ARE THE MINIMUM RECORDED DAILY AVERAGE FLOWS AT SITE FOR EACH MONTH INDIVIDUALLY.
    - MINIMUM RELEASES JUNE TO SEPTEMBER INCLUSIVE ARE 26 PERCENT OF LONG TERM AVERAGE FLOW AT SITE.
2. RESERVOIR FILLING FOR THE STIKINE TANZILLA PROJECT COULD BE COMPLETED IN 1½ MONTHS WITH OPERATIONAL POWER FLOWS FROM THE STIKINE SITE Z PROJECT WHILE MAINTAINING MINIMUM RECORDED DAILY AVERAGE FLOWS AT TELEGRAPH CREEK.

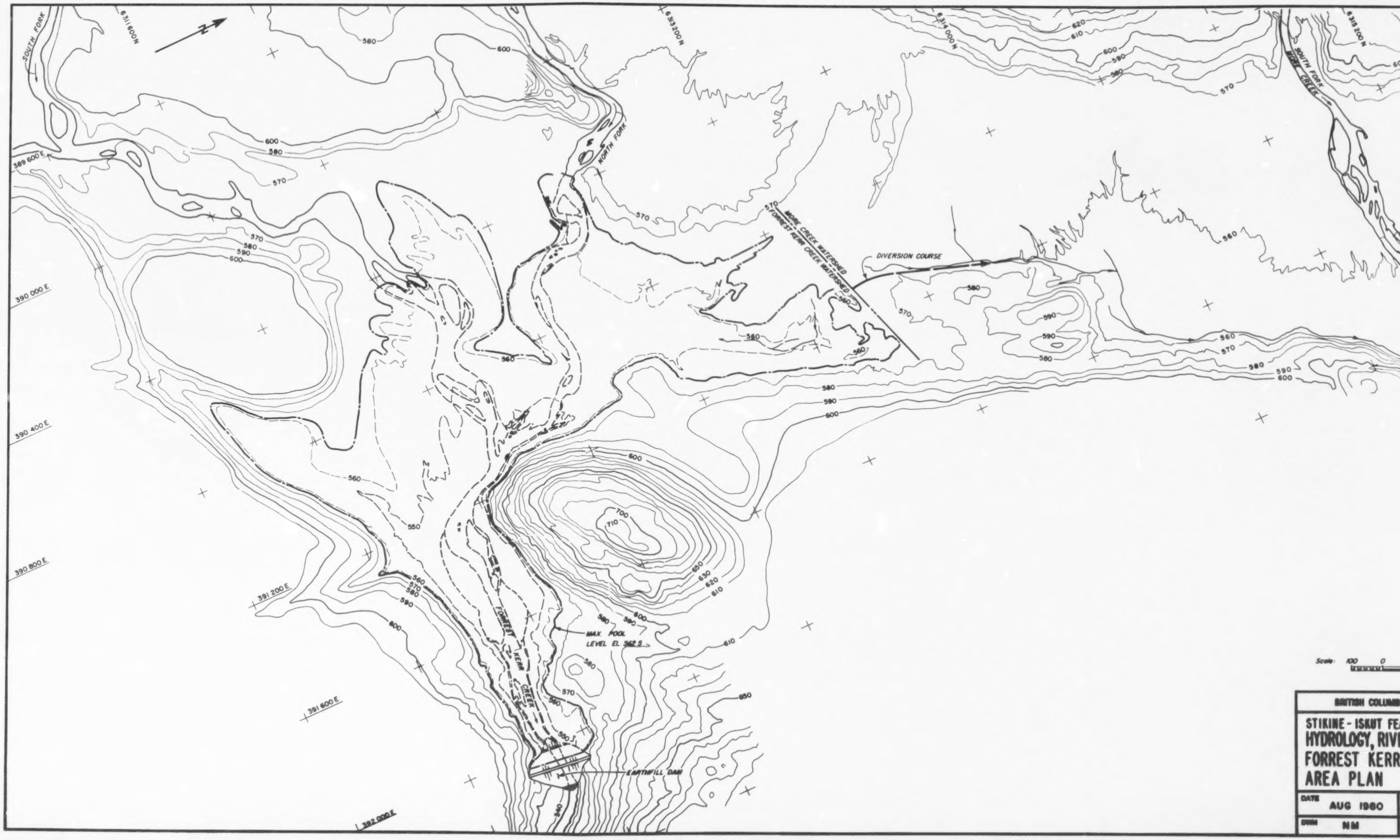
BRITISH COLUMBIA HYDRO AND POWER AUTHORITY

STIKINE - ISKUT FEASIBILITY STUDY

HYDROLOGY, RIVER REGIME & MORPHOLOGY
RESERVOIR FILLING CURVES

DATE AUG 1980	PLATE 3 - 3	R
DWN KL.	DWG No. 915 - C14 - D99	

REPORT No. H-1110

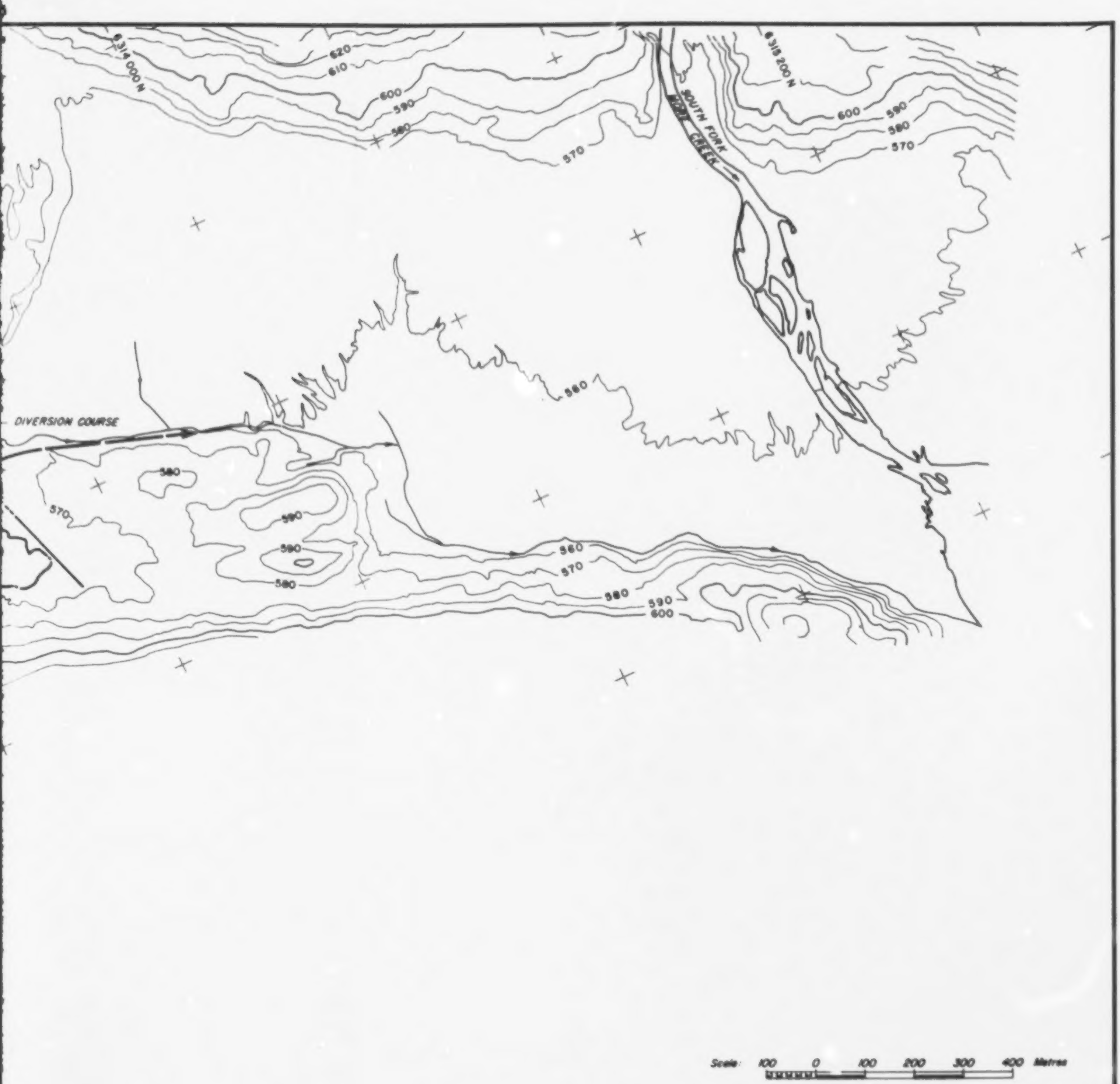

SOUTH FORK
6 311 600 N
N
580
600
6 313 200 N
6 314 000 N
620
610
600
590
580
570
6 315 200 N
SOUTH FORK
MORE CREEK
NORTH FORK
389 600 E
600
580
570
570
580
590
600
570
MORE CREEK WATERSHED
FORREST KERR CREEK WATERSHED
DIVERSION COURSE
560
390 000 E
580
570
580
590
590
580
560
570
580
590
600
560
580
560
580
590
600
390 400 E
600
560
700
710
550
390 800 E
650
630
620
610
391 200 E
560
570
580
590
FORREST
KERR
CREEK
600
580
590
600
MAX. POOL
LEVEL EL. 562.5
610
580
570
590
560
650
391 600 E
EARTHFILL DAM
540
392 000 E
Scale: 100 0

BRITISH COLUMB

STIKINE - ISKUT FEA
HYDROLOGY, RIV
FORREST KERR
AREA PLAN

DATE AUG 1980

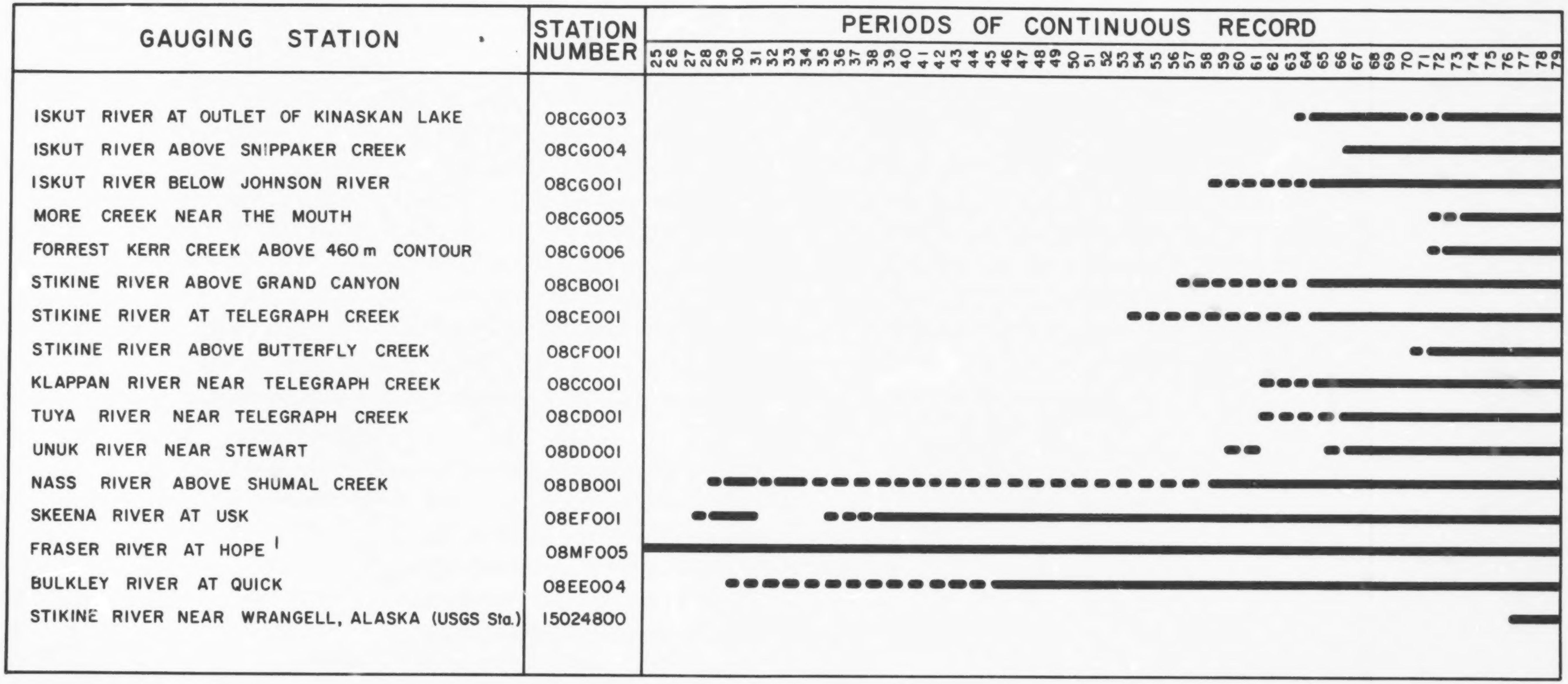
DWN NM


6 314 000 N
620
610
600
590
580
570
6 315 200 N
SOUTH FORK
MORE CREEK
600
590
580
570
580
DIVERSION COURSE
580
570
590
580
580
560
570
580
590
600
Scale: 100 0 100 200 300 400 Metres

BRITISH COLUMBIA HYDRO AND POWER AUTHORITY

STIKINE - ISKUT FEASIBILITY STUDY
HYDROLOGY, RIVER REGIME & MORPHOLOGY
FORREST KERR DIVERSION DAM
AREA PLAN

DATE AUG 1980	PLATE 3-4	R
DWN NM	DWG No. 915 - C14 -U100	



GAUGING STATION	STATION NUMBER
ISKUT RIVER AT OUTLET OF KINASKAN LAKE	08CG003
ISKUT RIVER ABOVE SNIPPAKER CREEK	08CG004
ISKUT RIVER BELOW JOHNSON RIVER	08CG001
MORE CREEK NEAR THE MOUTH	08CG005
FORREST KERR CREEK ABOVE 460 m CONTOUR	08CG006
STIKINE RIVER ABOVE GRAND CANYON	08CB001
STIKINE RIVER AT TELEGRAPH CREEK	08CE001
STIKINE RIVER ABOVE BUTTERFLY CREEK	08CF001
KLAPPAN RIVER NEAR TELEGRAPH CREEK	08CC001
TUYA RIVER NEAR TELEGRAPH CREEK	08CD001
UNUK RIVER NEAR STEWART	08DD001
NASS RIVER ABOVE SHUMAL CREEK	08DB001
SKEENA RIVER AT USK	08EF001
FRASER RIVER AT HOPE [1]	08MF005
BULKLEY RIVER AT QUICK	08EE004
STIKINE RIVER NEAR WRANGELL, ALASKA (USGS Sta.)	15024800

NOTE:

1. STRE
RIVE
FROM

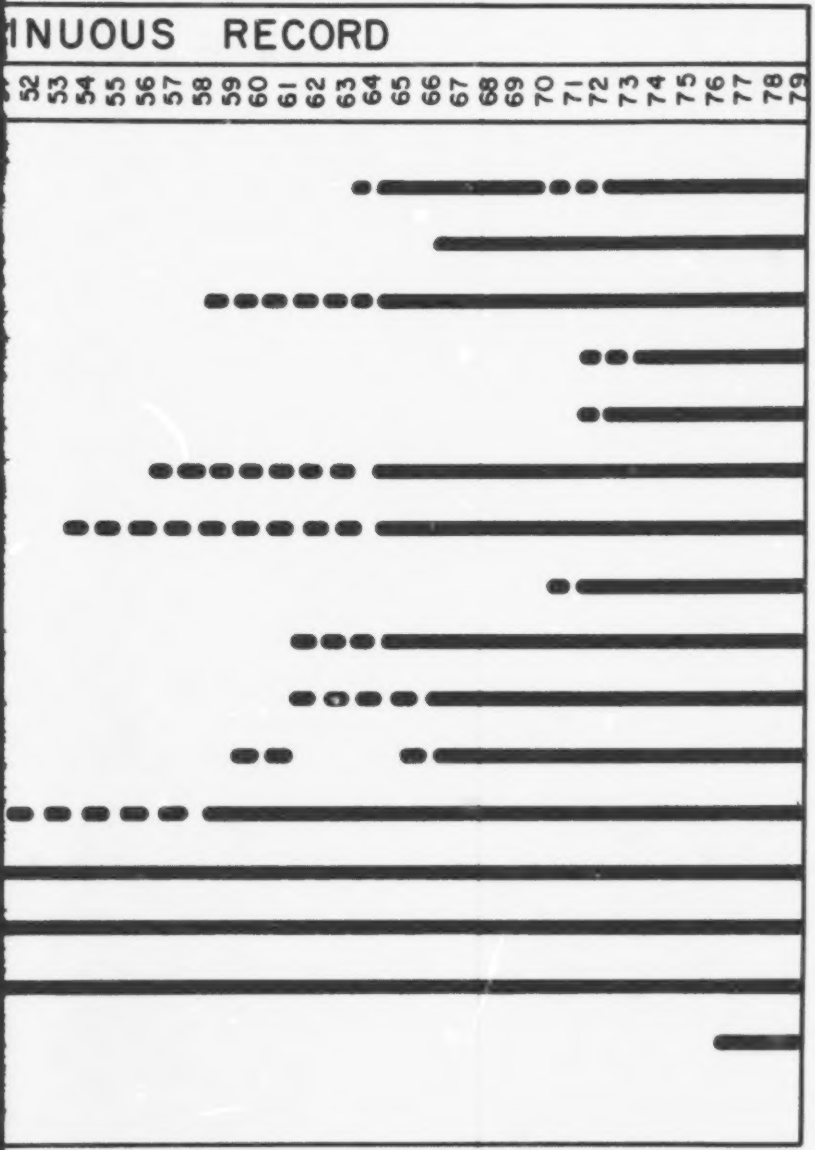
BRITIS

STIKI
HYDR
AVAI

DATE A

DWN K

REPORT



N O T E:

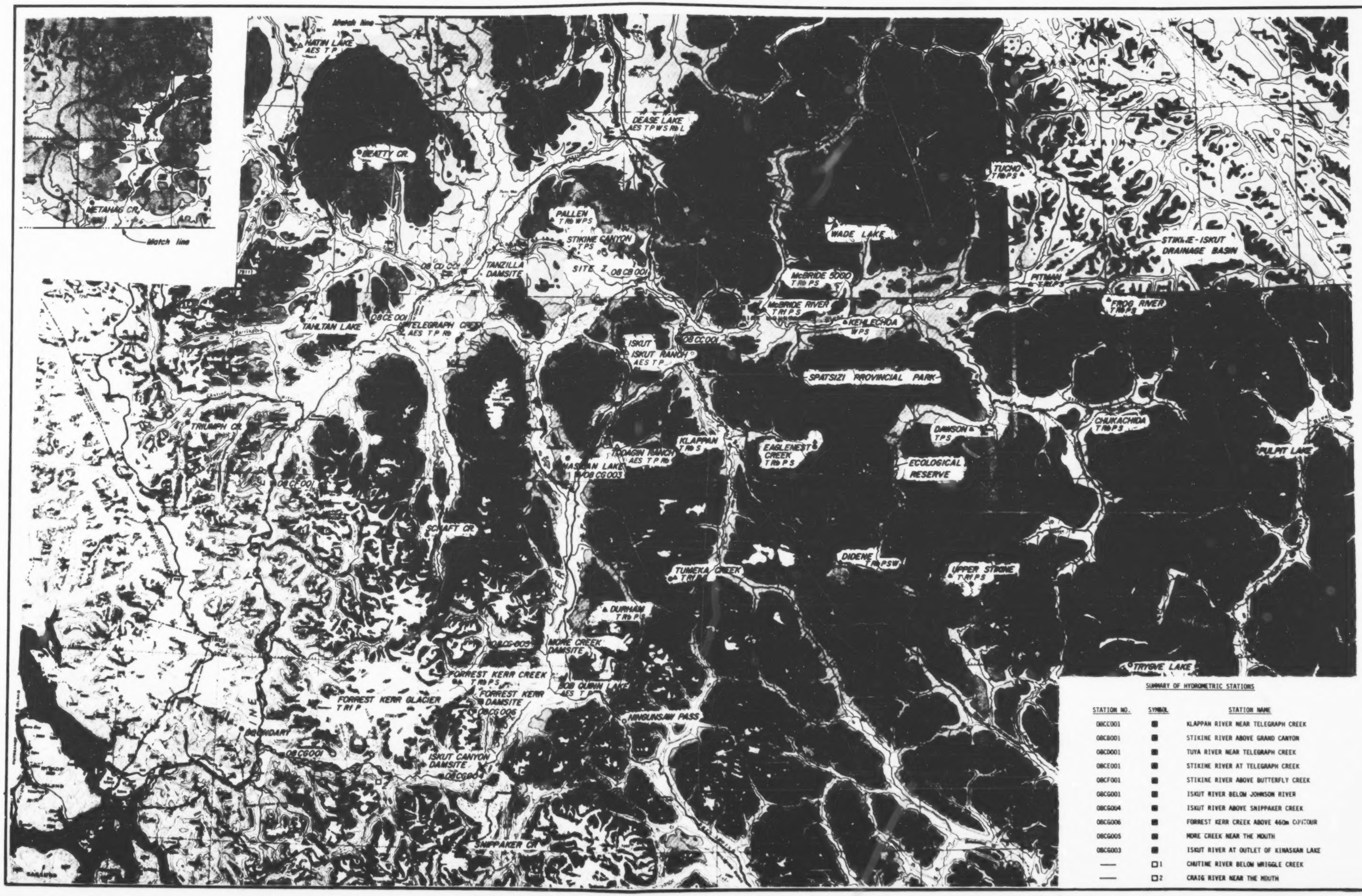
1. STREAMFLOW RECORDS FOR FRASER RIVER AT HOPE ARE CONTINUOUS FROM MAY, 1912.

BRITISH COLUMBIA HYDRO AND POWER AUTHORITY

STIKINE - ISKUT FEASIBILITY STUDY
HYDROLOGY, RIVER REGIME & MORPHOLOGY
AVAILABLE STREAMFLOW DATA

DATE AUG 1980
PLATE 4 - 1
DWN KL
DWG. No. 915 - C14 - C101

REPORT No H-1110


Match line
HATIN LAKE AES T P
BEATTY CR.
METAHAG CR.
Match line
DEASE LAKE AES T P W S Rb L
PALLEN T Rb W P S
STIKINE CANYON T P S
SITE Z 08CB001
TANZILLA DAMSITE
08CD001
TAHLTAN LAKE
08CE001
TELEGRAPH CREEK AES T P Rb
ISKUT
ISKUT RANCH AES T P
08CC001
TUCHO T Rb P S
WADE LAKE
McBRIDE 5000 T Rb P S
McBRIDE RIVER T Rb P S
KEHLECHOA W P S
PITMAN
STIKINE-ISKUT DRAINAGE BASIN
FROG RIVER T Rb P S
SPATSIZI PROVINCIAL PARK
TRIUMPH CR.
08CF001
KLAPPAN T Rb S
TODAGIN RANCH AES T P Rb
KINASKAN LAKE 08CG003
EAGLENEST CREEK T Rb P S
DAWSON T P S
ECOLOGICAL RESERVE
CHUKACHIDA T Rb P S
PULPIT LAKE
SCHAFT CR.
TUMEKA CREEK T Rb P
DIDENE T Rb P S W
UPPER STIKINE T Rb P S
DURHAM T Rb P
08CG005
MORE CREEK DAMSITE
FORREST KERR CREEK T Rb P S
FORREST KERR DAMSITE
08CG006
FORREST KERR GLACIER T Rf P
BOB QUINN LAKE AES T
NINGUNSAW PASS
BOUNDARY
08CG001
ISKUT CANYON DAMSITE
08CG004
SNIPPAKER CR.
TRYGVE LAKE

SUMMARY OF HYDROMETRIC STATIONS

STATION NO.	SYMBOL	STATION NAME
08CC001	■	KLAPPAN RIVER NEAR TELEGRAPH CREEK
08CB001	■	STIKINE RIVER ABOVE GRAND CANYON
08CD001	■	TUYA RIVER NEAR TELEGRAPH CREEK
08CE001	■	STIKINE RIVER AT TELEGRAPH CREEK
08CF001	■	STIKINE RIVER ABOVE BUTTERFLY CREEK
08CG001	■	ISKUT RIVER BELOW JOHNSON RIVER
08CG004	■	ISKUT RIVER ABOVE SNIPPAKER CREEK
08CG006	■	FORREST KERR CREEK ABOVE 460m CONTOUR
08CG005	■	MORE CREEK NEAR THE MOUTH
08CG003	■	ISKUT RIVER AT OUTLET OF KINASKAN LAKE
—	□1	CHUTINE RIVER BELOW WRIGGLE CREEK
—	□2	CRAIG RIVER NEAR THE MOUTH

STIKINE BASIN

LEGEND

T	Ther
Rb	Belf
Rf	Fish
P	Stor
S	Snow
W	Anei
L	Sola
▲	BC Stat
△	AES Prev
●	Wat in J
○	Wat Prev
■	Wat
□	BC

Scale= 10

BRITISH

STIKINE - IS
HYDROLOGY
HYDROMET
NETWOR

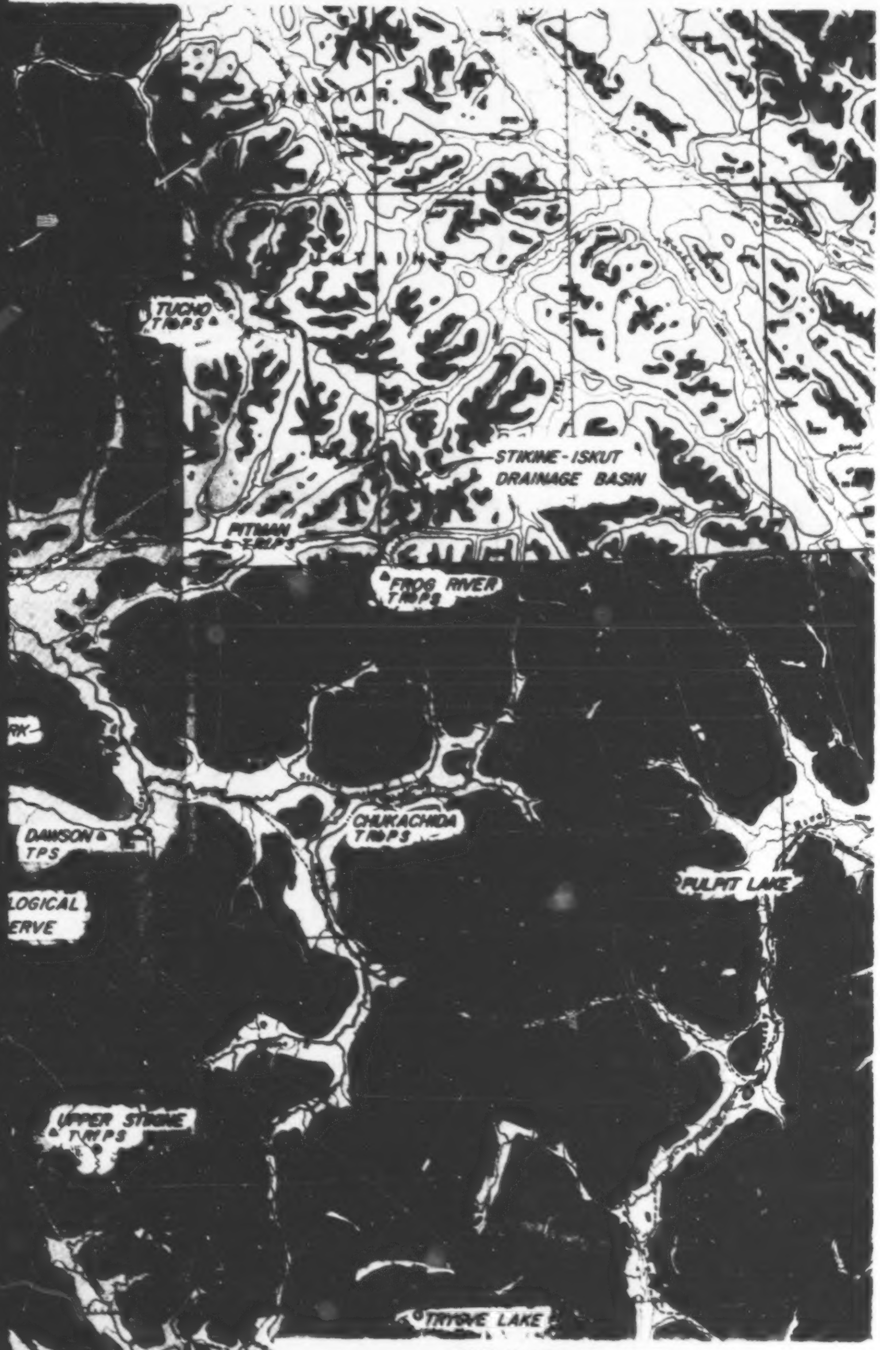
DATE AUG 196

DWN K.L.

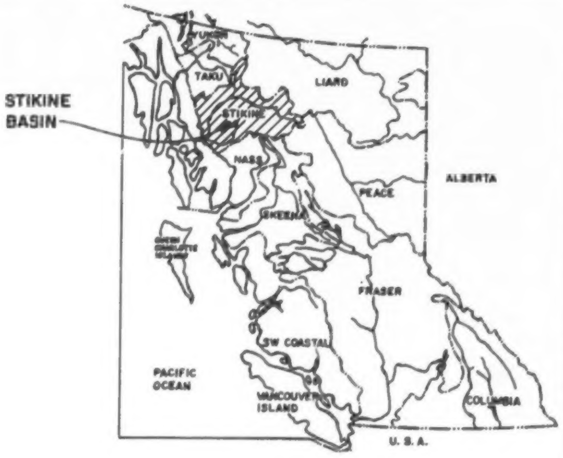
REPORT No. H-111

Therm
Belfo
Fishe
Stand
Snow
Anem
Solar
BC H
Statio
AES
Previ
Water
in Ju
Water
Previ
Water
BC H

ITISH C
- ISK
OGY,
NET
ORK
198
-1110



SSIAR
UNTAINS
TUCHO T/P S
PITMAN T/P S
STIKINE-ISKUT DRAINAGE BASIN
FROG RIVER T/P S
RK
DAWSON TPS
LOGICAL ERVE
CHUKACHIDA T/P S
PULPIT LAKE
UPPER STIKINE T/P S
TRYGVE LAKE



STIKINE BASIN
YUKON
TAKU
LIARD
STIKINE
NASS
ALBERTA
PEACE
SKEENA
QUEEN CHARLOTTE ISLANDS
FRASER
SW COASTAL
PACIFIC OCEAN
VANCOUVER ISLAND
COLUMBIA
U.S.A.

KEY PLAN

LEGEND

T	Thermograph & Maximum - Minimum Thermometer
Rb	Belfort Recording Rain Gauge
Rf	Fisher-Porter Recording Rain Gauge
P	Standard Rain Gauge
S	Snow Stakes
W	Anemometer
L	Solarimeter
▲	BC Hydro / A.S.B. Automatic Climatological Network Stations Installed in June 1979.
△	AES Manual Climatological Stations Installed Previous to 1979.
●	Water Investigations Branch Snow Course Installed in June 1979
○	Water Investigations Branch Snow Course, Installed Previous to 1979
■	Water Survey of Canada Gauging Station
□	BC Hydro Metering Section

SUMMARY OF HYDROMETRIC STATIONS

STATION NO.	SYMBOL	STATION NAME
08CC001	■	KLAPPAN RIVER NEAR TELEGRAPH CREEK
08CB001	■	STIKINE RIVER ABOVE GRAND CANYON
08CD001	■	TUYA RIVER NEAR TELEGRAPH CREEK
08CE001	■	STIKINE RIVER AT TELEGRAPH CREEK
08CF001	■	STIKINE RIVER ABOVE BUTTERFLY CREEK
08CG001	■	ISKUT RIVER BELOW JOHNSON RIVER
08CG004	■	ISKUT RIVER ABOVE SNIPPAKER CREEK
08CG006	■	FORREST KERR CREEK ABOVE 460m CONTOUR
08CG005	■	MORE CREEK NEAR THE MOUTH
08CG003	■	ISKUT RIVER AT OUTLET OF KINASKAN LAKE
—	□1	CHUTINE RIVER BELOW WRIGGLE CREEK
—	□2	CRAIG RIVER NEAR THE MOUTH

Scale = 10 0 10 20 30 40 Kilometres

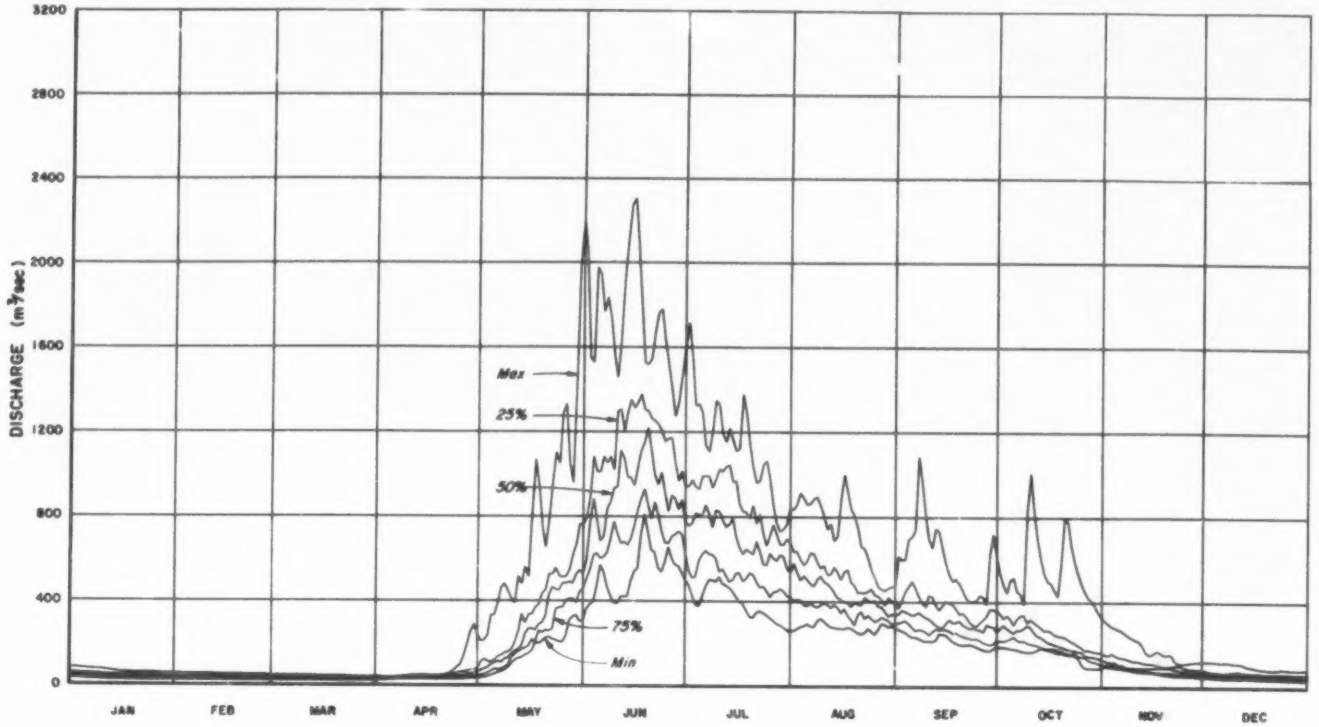
BRITISH COLUMBIA HYDRO AND POWER AUTHORITY

STIKINE - ISKUT FEASIBILITY STUDY

HYDROLOGY, RIVER REGIME & MORPHOLOGY HYDROMETRIC AND CLIMATOLOGICAL NETWORKS

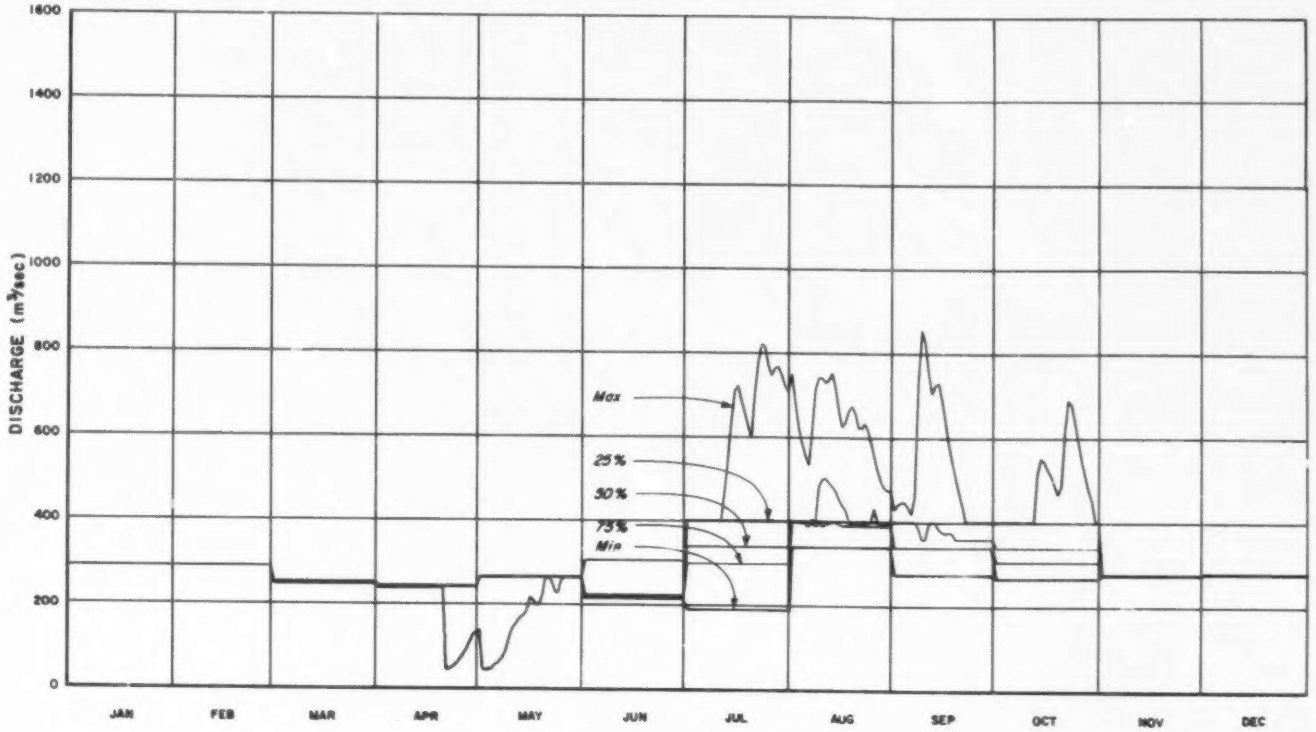
DATE AUG 1980	PLATE 4 - 2	R
DWN K.L.	DWG No. 915 - C14 - U102	

REPORT No. H-1110



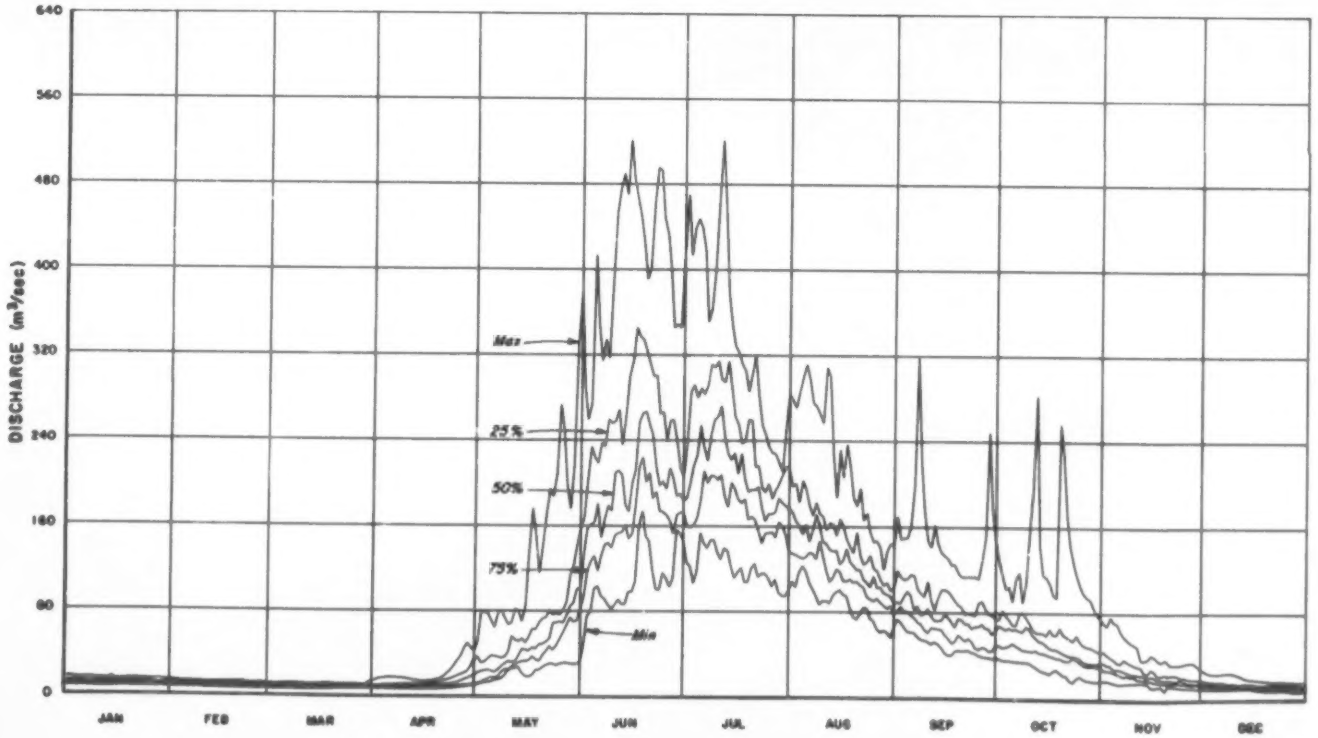
STIKINE RIVER AT SITE Z

(NATURAL FLOWS 1967 - 1978)



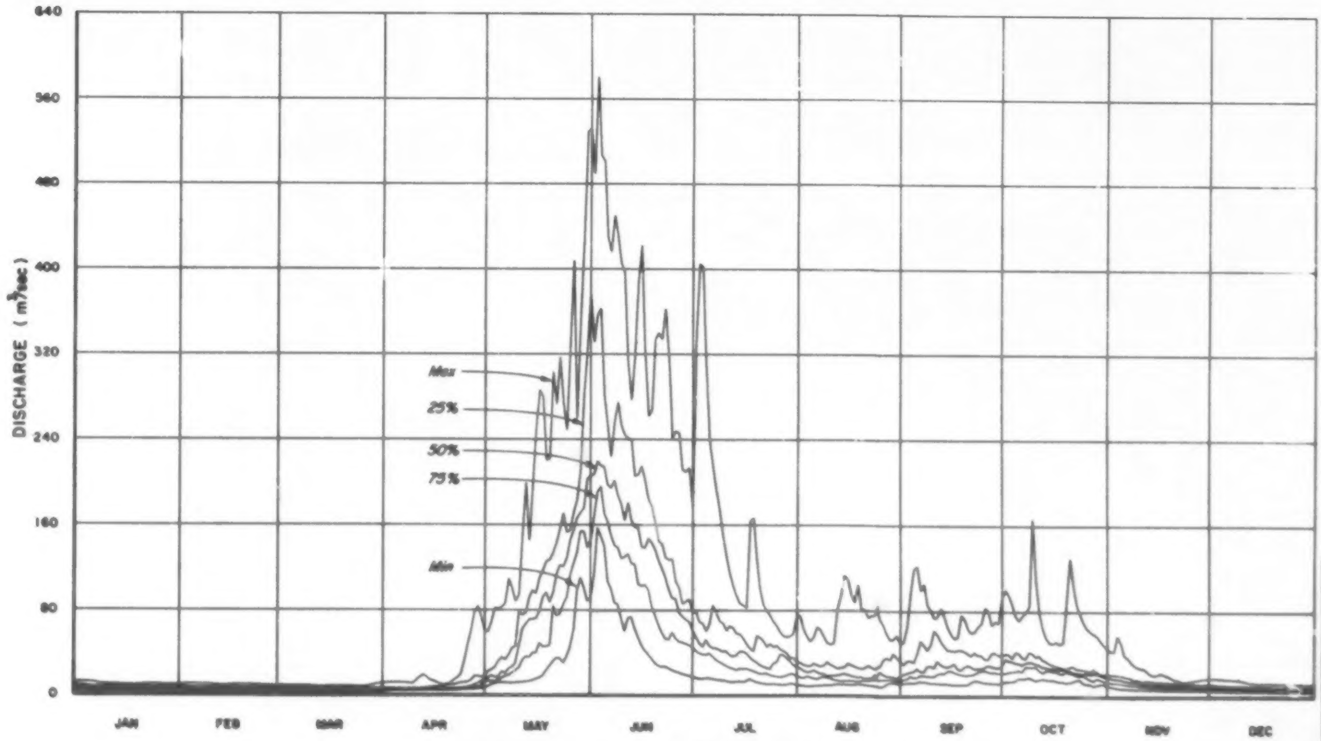
STIKINE RIVER AT SITE Z

(REGULATED FLOWS 1967 - 1978)



KLAPPAN RIVER NEAR TELEGRAPH CREEK

(NATURAL FLOWS 1962 - 1979)



TUYA RIVER NEAR TELEGRAPH CREEK

(NATURAL FLOWS 1962 - 1976)

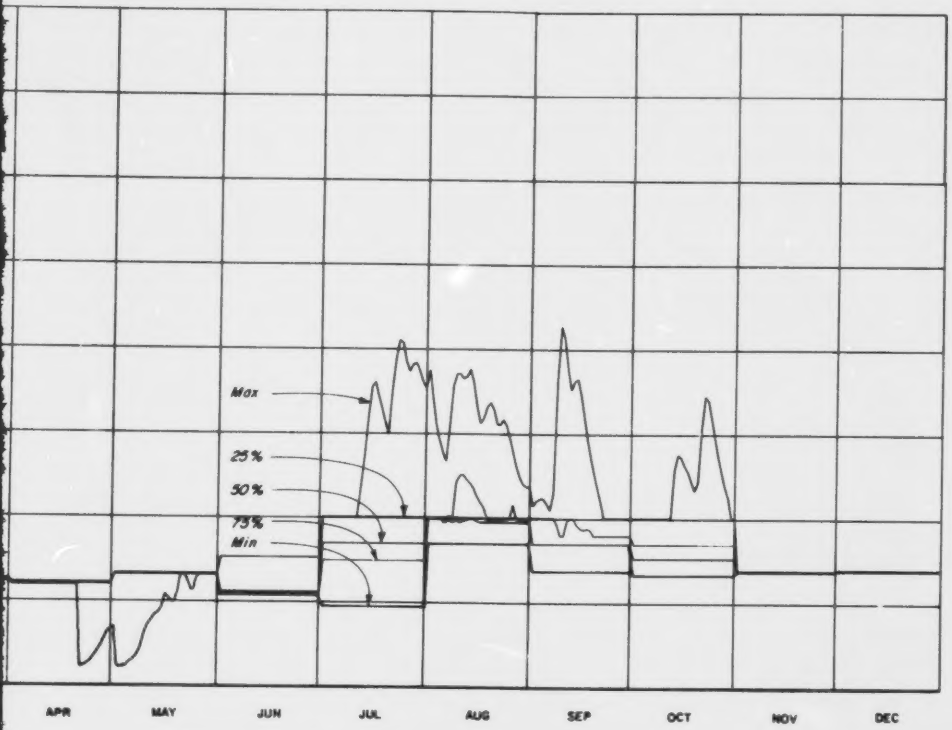
BRITISH COL

STIKINE - ISKUT

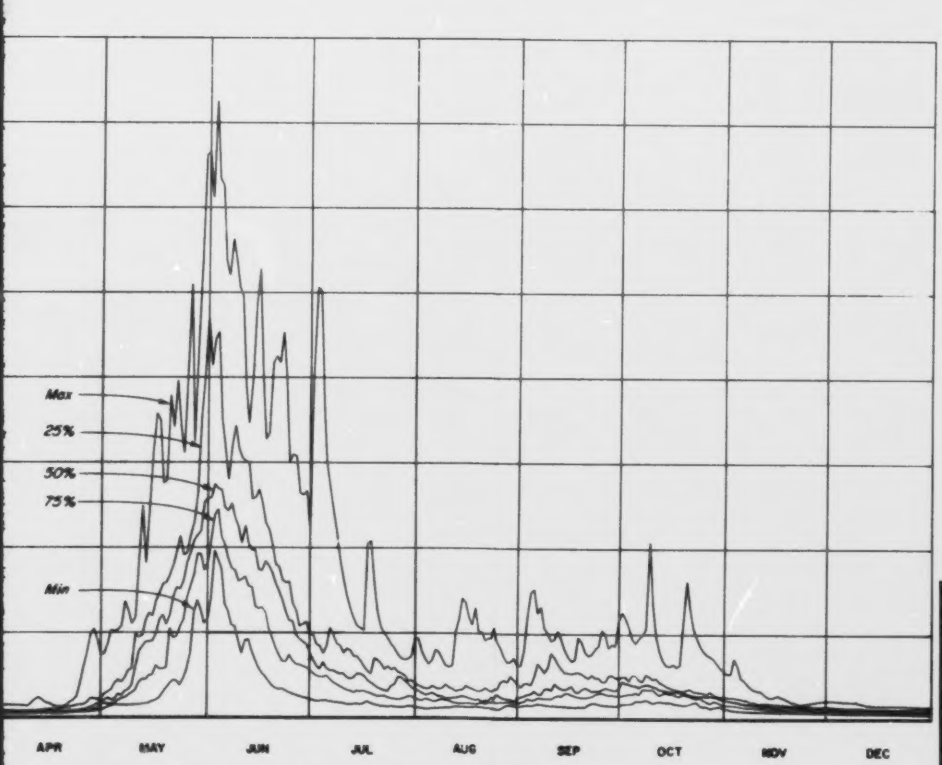
HYDROLOGY,
DAILY FLOW

DATE AUG 1980

DWN K.L.



STIKINE RIVER AT SITE Z
(REGULATED FLOWS 1967 - 1978)



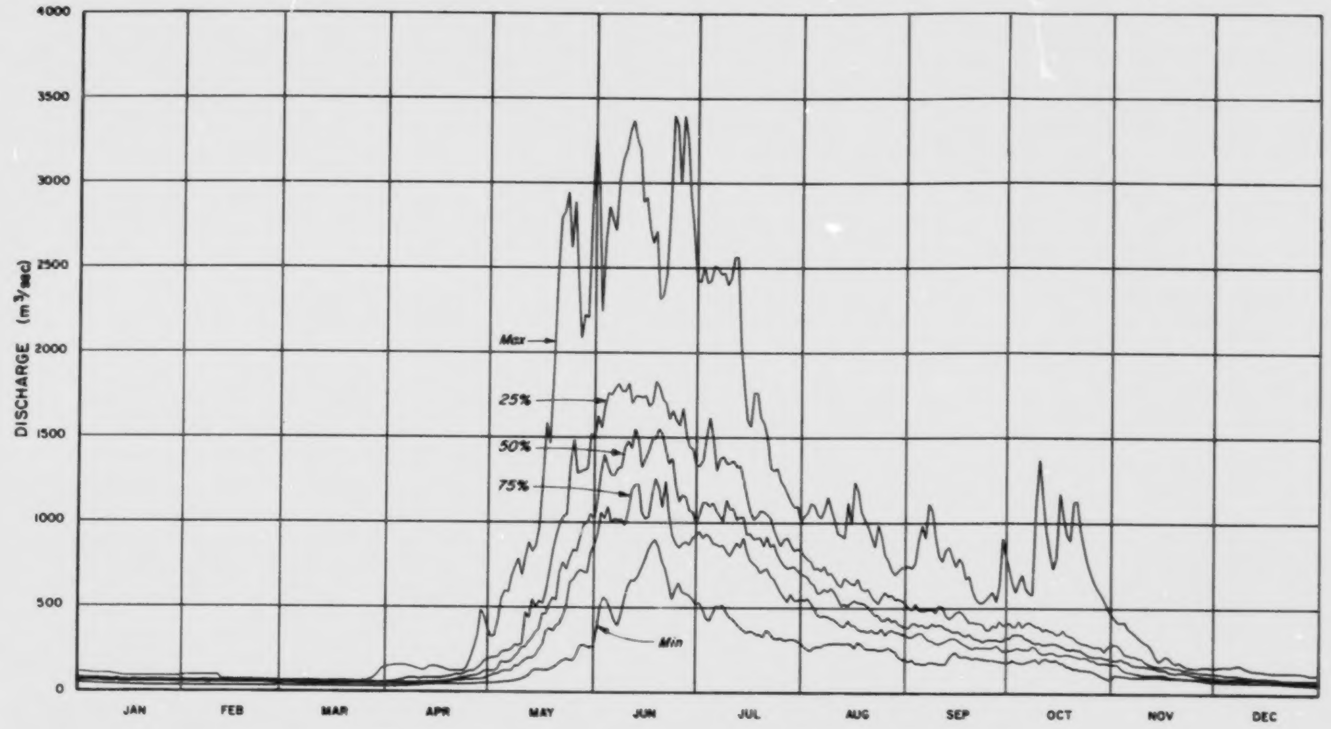
TUYA RIVER NEAR TELEGRAPH CREEK
(NATURAL FLOWS 1962 - 1978)

BRITISH COLUMBIA HYDRO AND POWER AUTHORITY

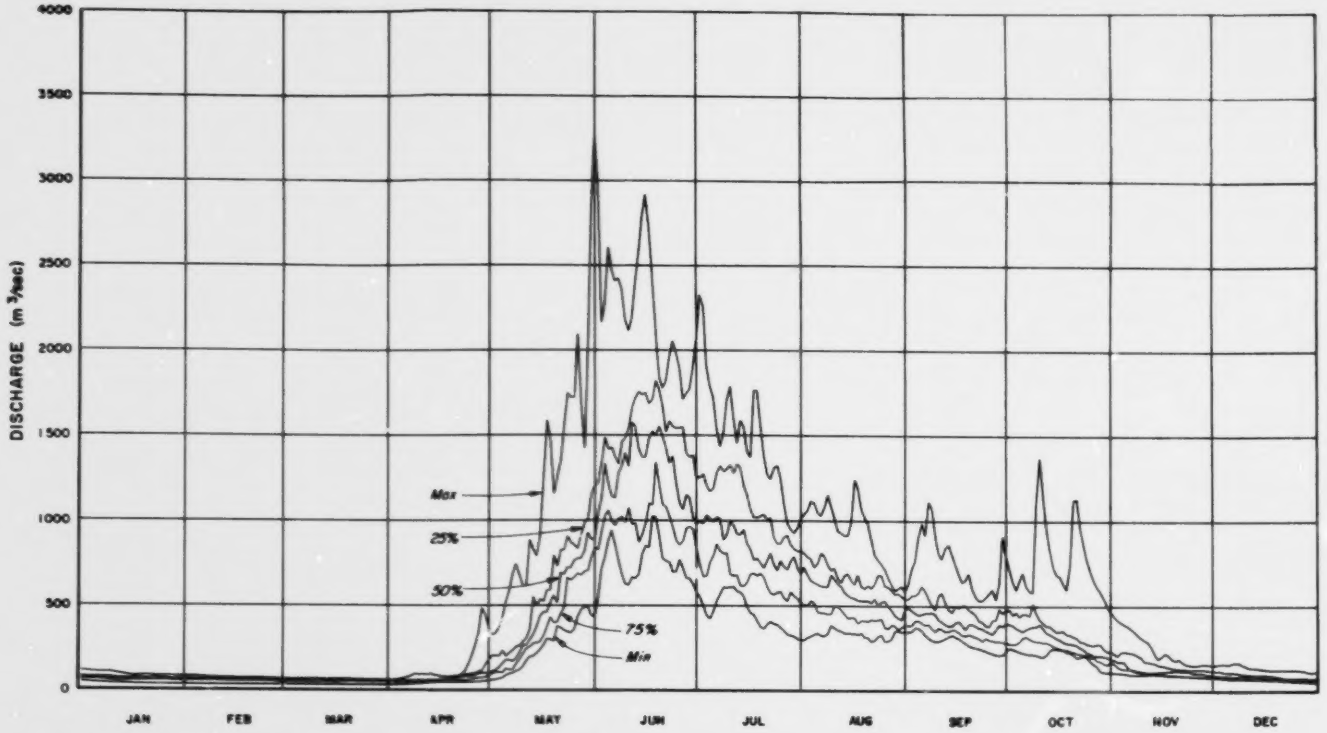
STIKINE - ISKUT FEASIBILITY STUDY

HYDROLOGY, RIVER REGIME & MORPHOLOGY
DAILY FLOW PROBABILITES - SHEET 1 OF 4

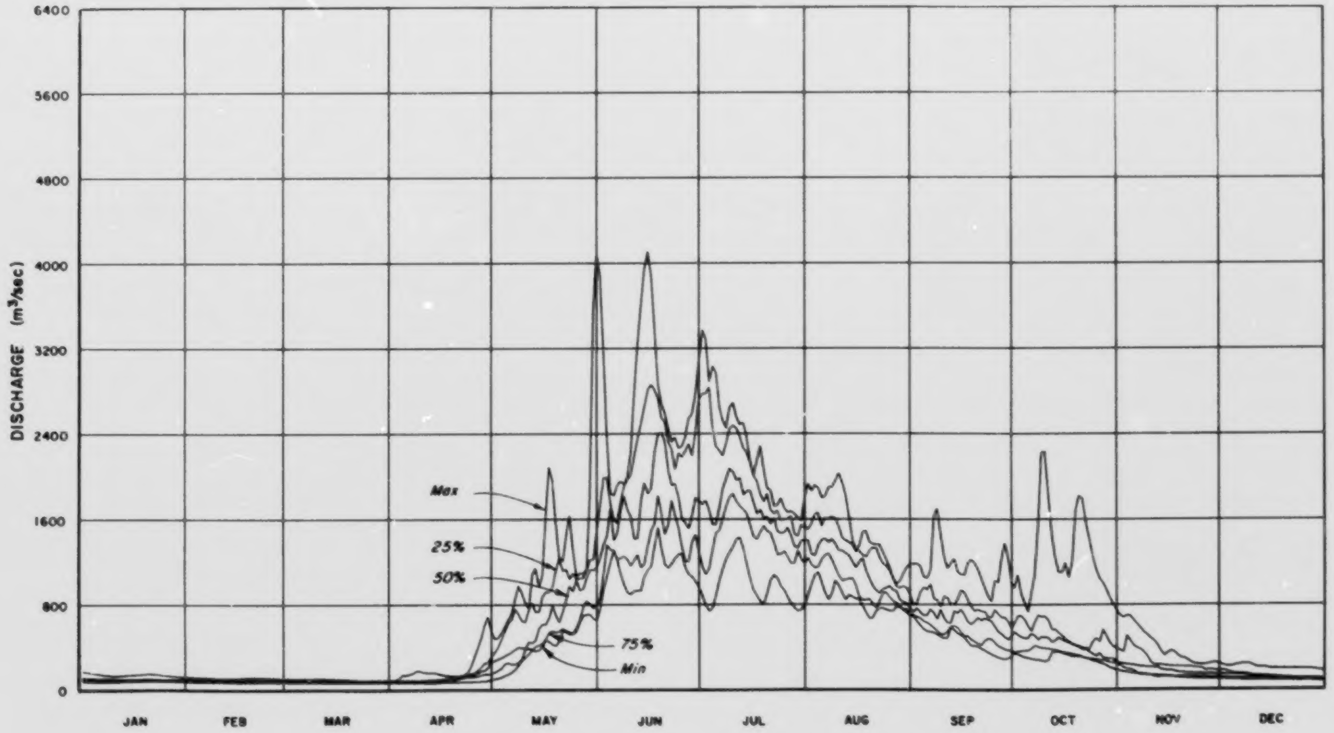
DATE AUG 1980	PLATE 4 - 3	R
DWN K.L.	DWG No. 915 - C14 - U103	



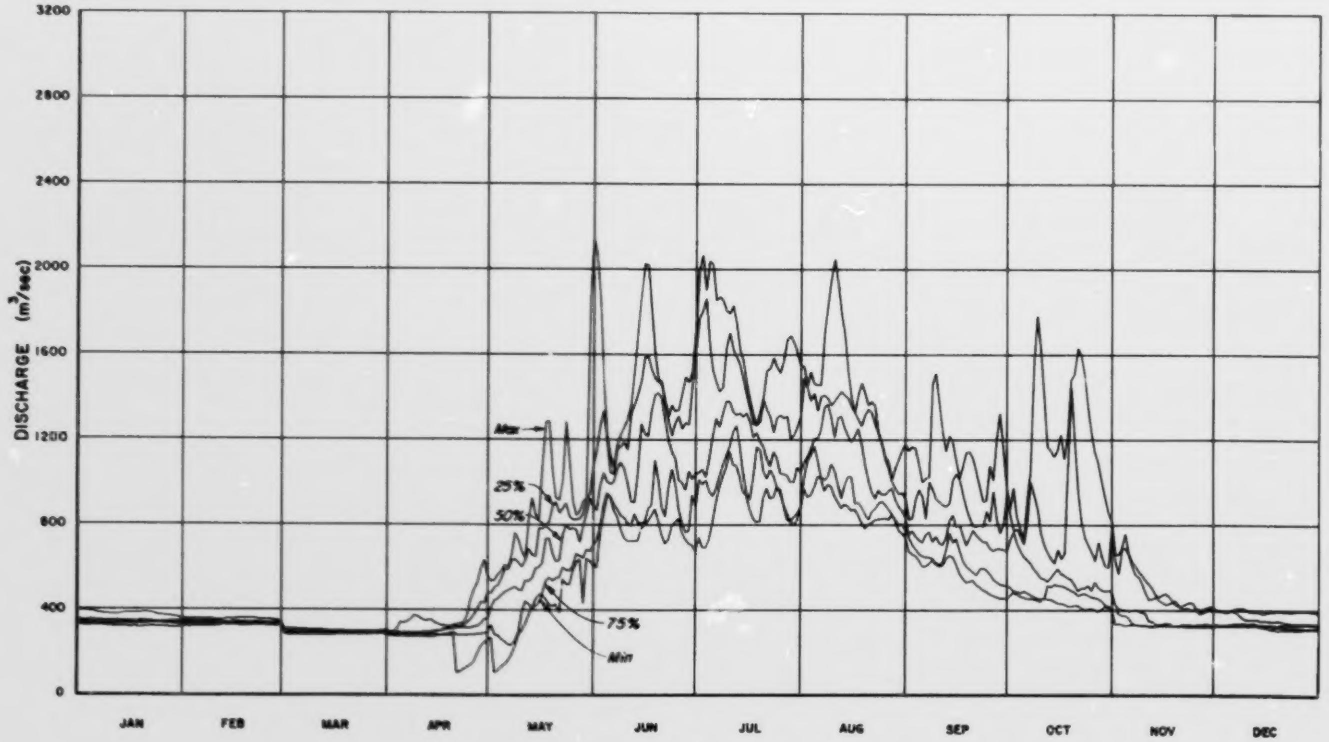
STIKINE RIVER AT TELEGRAPH CREEK
(NATURAL FLOWS 1954 - 1979)



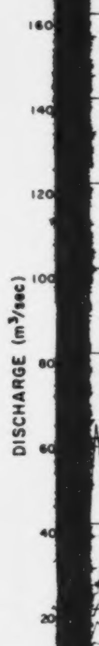
STIKINE RIVER AT TELEGRAPH CREEK
(NATURAL FLOWS 1967 - 1978)

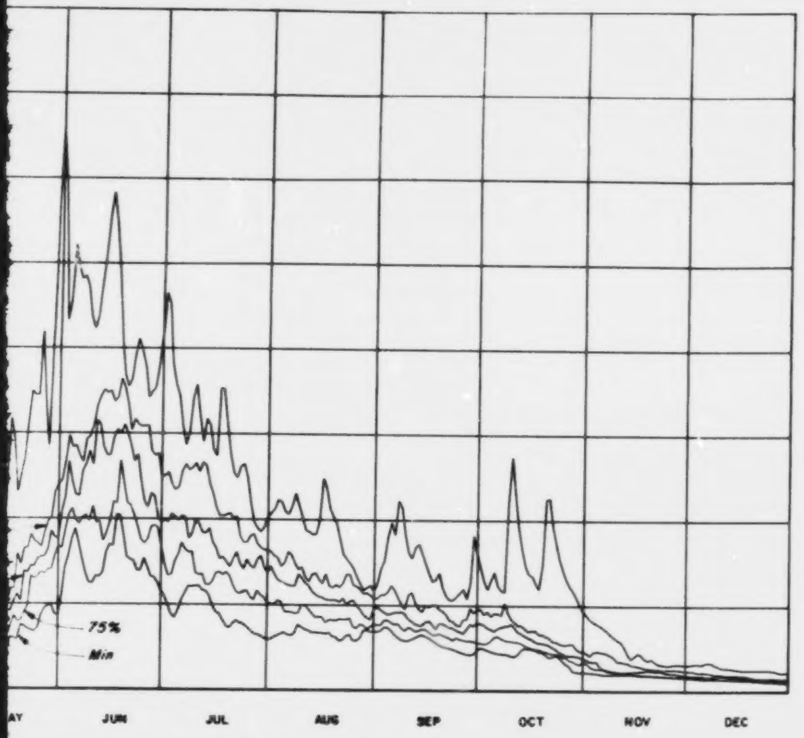


STIKINE RIVER ABOVE BUTTERFLY CREEK
(NATURAL FLOWS 1972 - 1978)

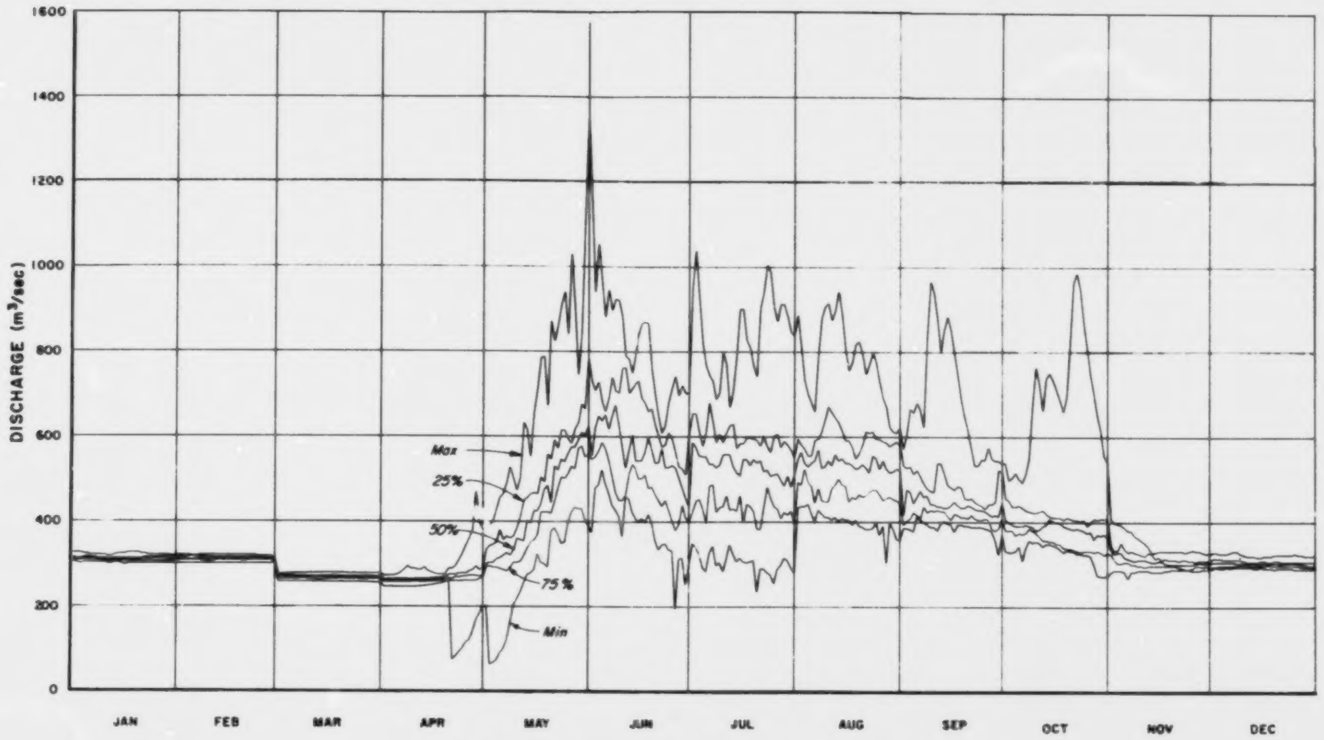


STIKINE RIVER ABOVE BUTTERFLY CREEK
(REGULATED FLOWS 1972 - 1978)

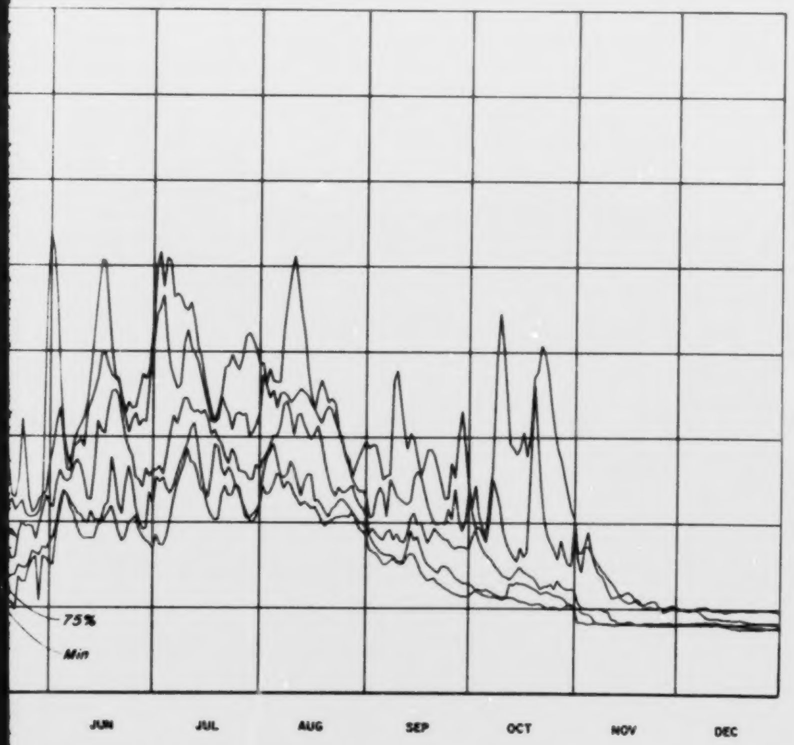




E RIVER AT TELEGRAPH CREEK
(NATURAL FLOWS 1967 - 1978)



STIKINE RIVER AT TELEGRAPH CREEK
(REGULATED FLOWS 1967 - 1978)



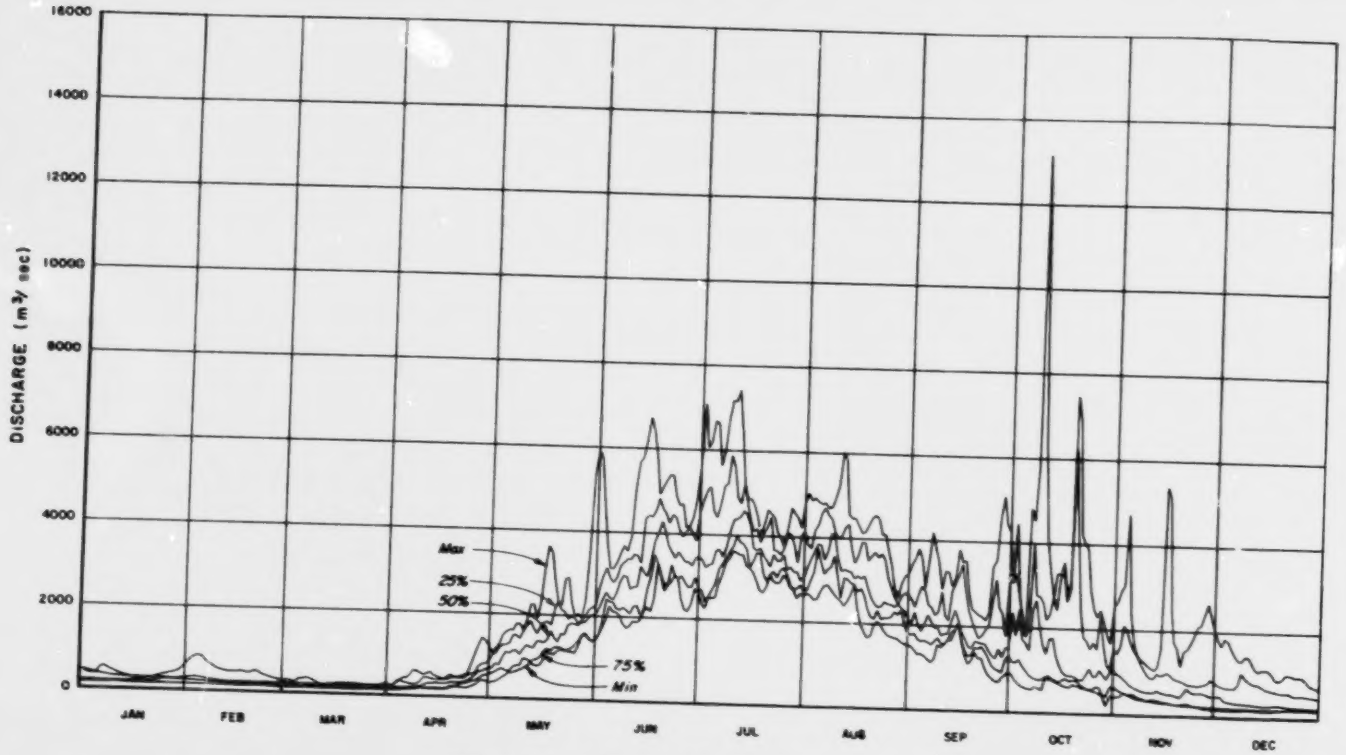
RIVER ABOVE BUTTERFLY CREEK
REGULATED FLOWS 1972 - 1978)

BRITISH COLUMBIA HYDRO AND POWER AUTHORITY

STIKINE - ISKUT FEASIBILITY STUDY

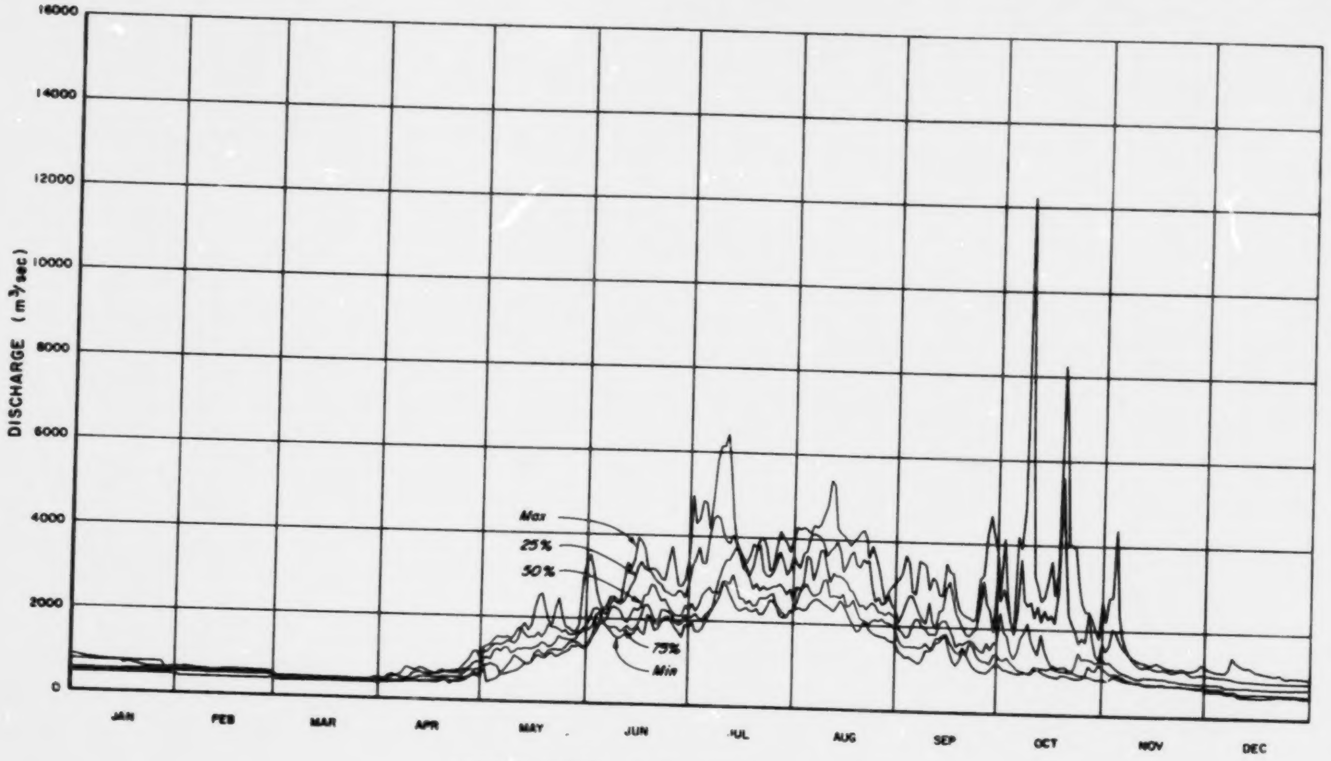
HYDROLOGY, RIVER REGIME & MORPHOLOGY
DAILY FLOW PROBABILITES - SHEET 2 OF 4

DATE AUG 1980
PLATE 4 - 3
R
DWN K.L.
DWG No. 915 - C14 - X104



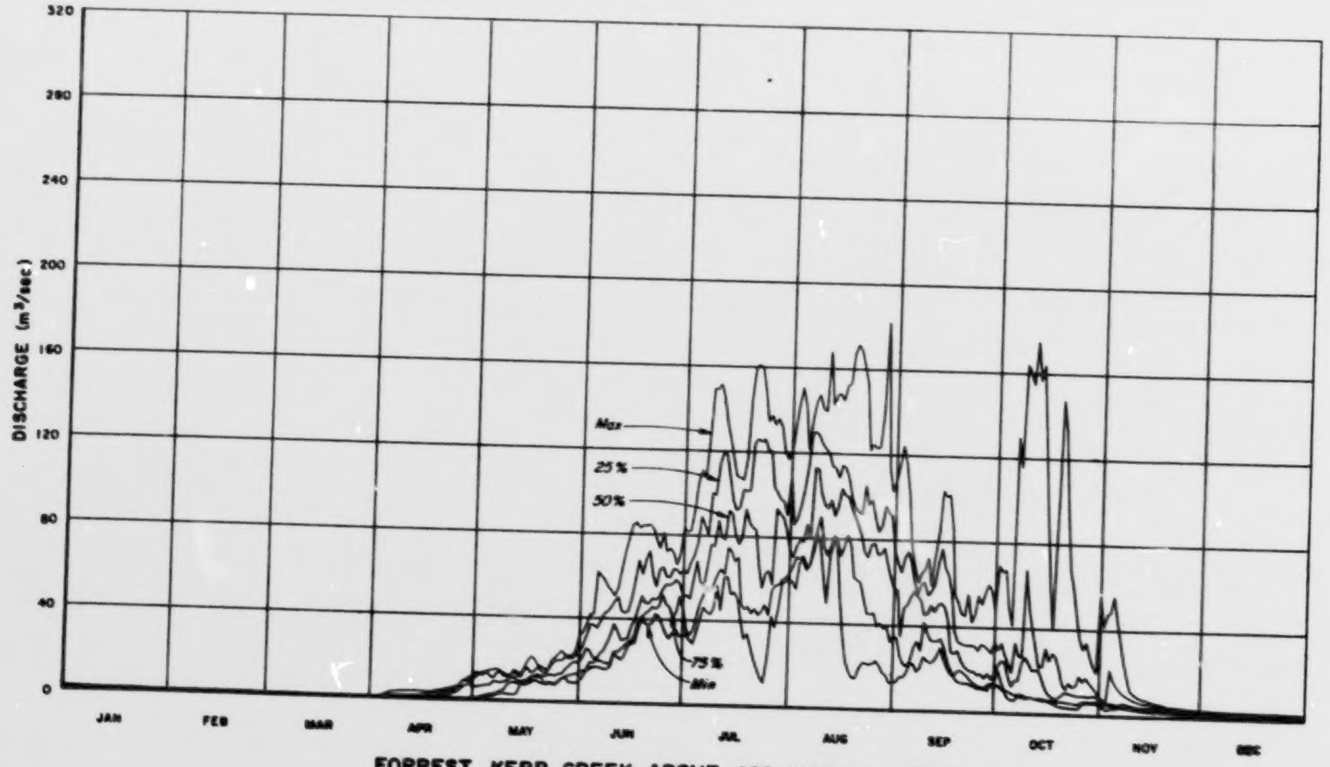
STIKINE RIVER NEAR WRANGELL, ALASKA

(NATURAL FLOWS 1972 - 1977)



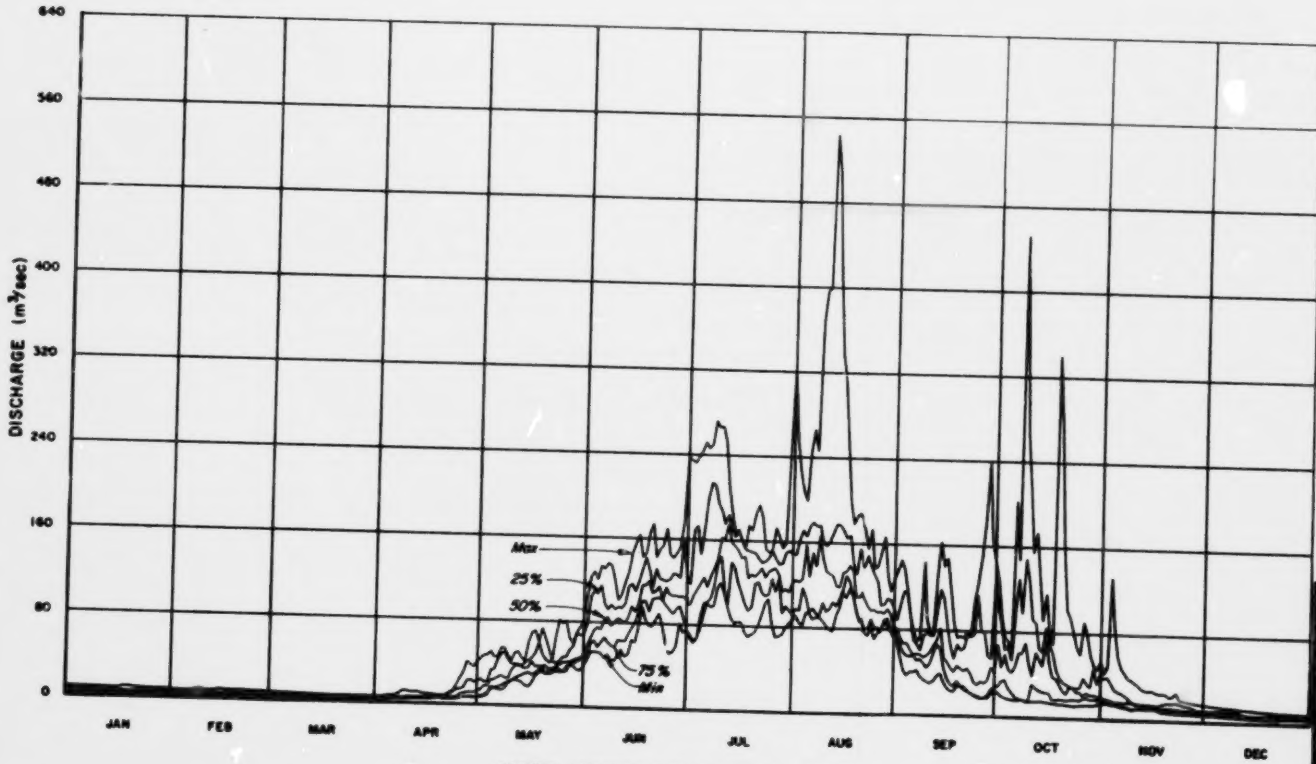
STIKINE RIVER NEAR WRANGELL, ALASKA

(REGULATED FLOWS 1972 - 1977)



FORREST KERR CREEK ABOVE 460 METRE CONTOUR

(NATURAL FLOWS 1972 - 1979)



MORE CREEK NEAR THE MOUTH

(NATURAL FLOWS 1962 - 1978)

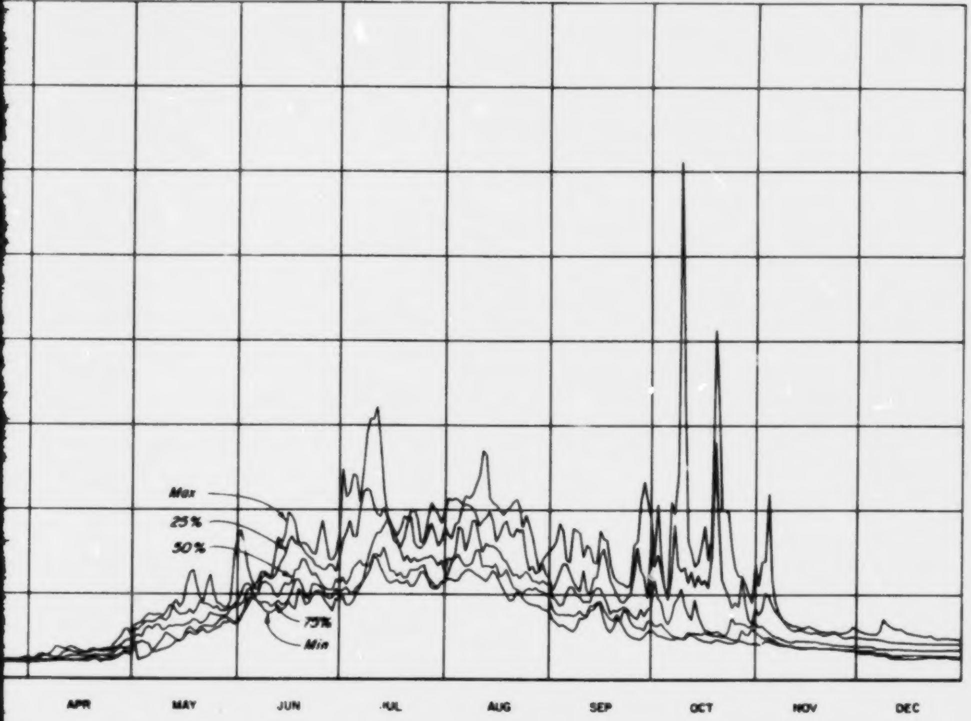
BRITISH COLUM

STIKINE - ISKUT

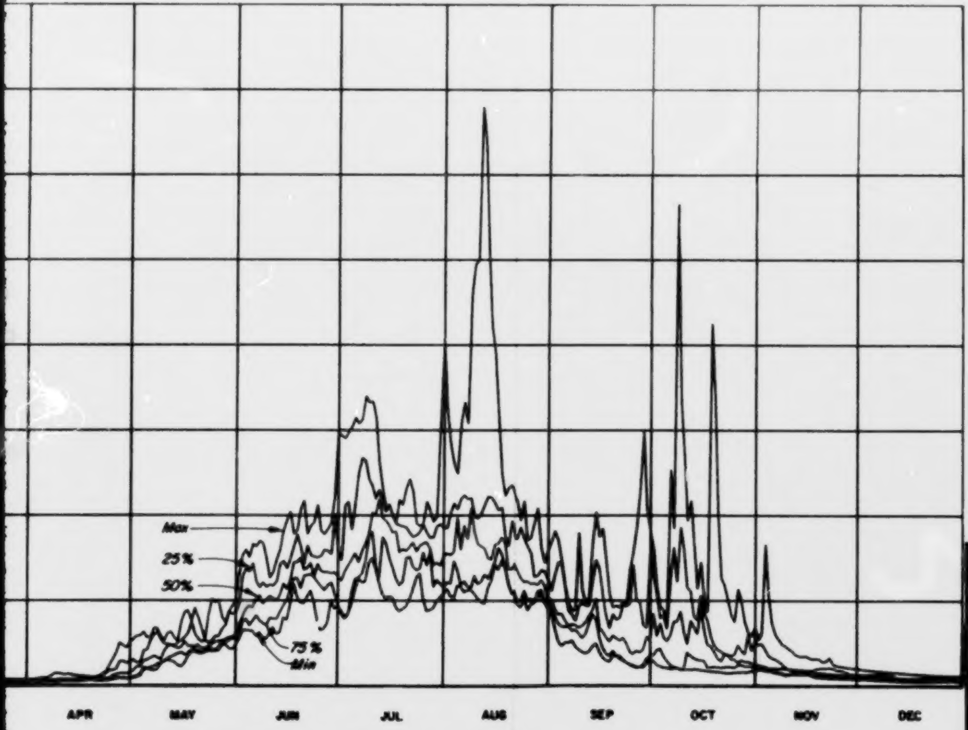
HYDROLOGY, R
DAILY FLOW P

DATE AUG 1980

DWN



STIKINE RIVER NEAR WRANGELL, ALASKA
(REGULATED FLOWS 1972 - 1977)



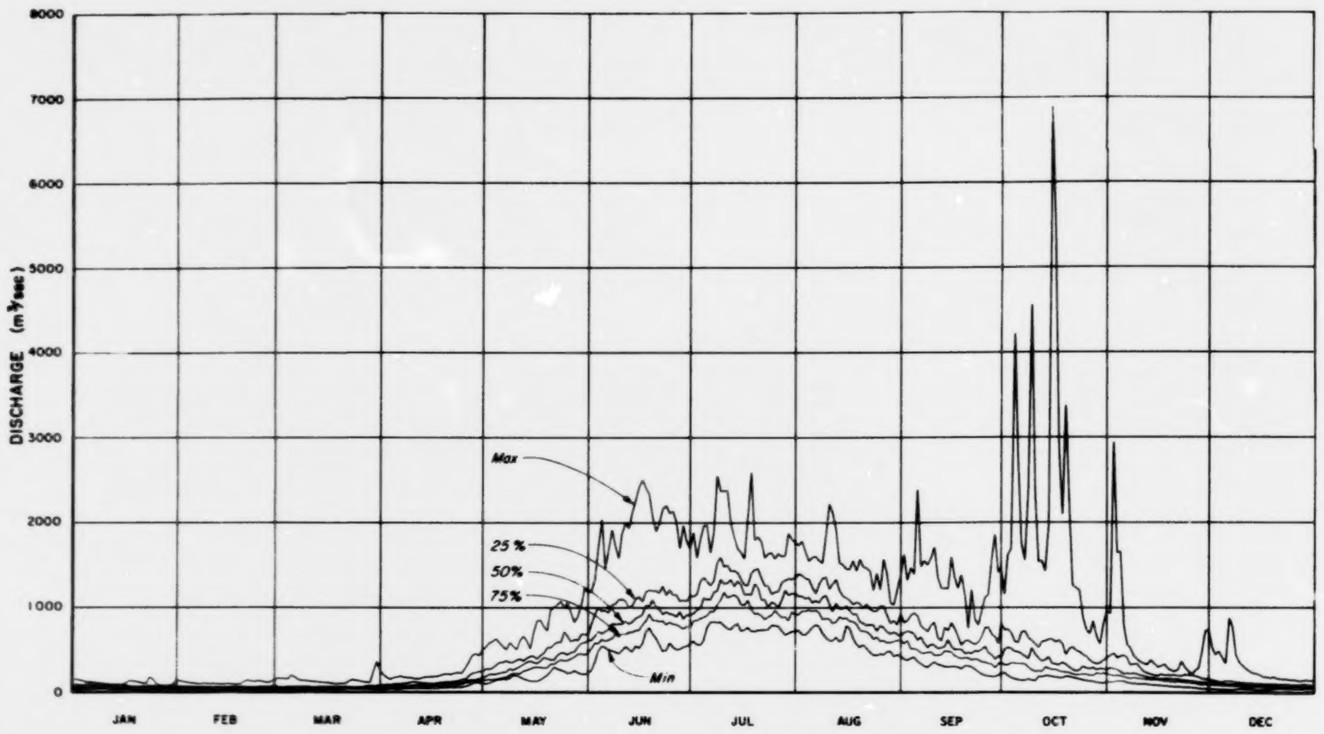
MORE CREEK NEAR THE MOUTH
(NATURAL FLOWS 1962 - 1978)

BRITISH COLUMBIA HYDRO AND POWER AUTHORITY

STIKINE - ISKUT FEASIBILITY STUDY

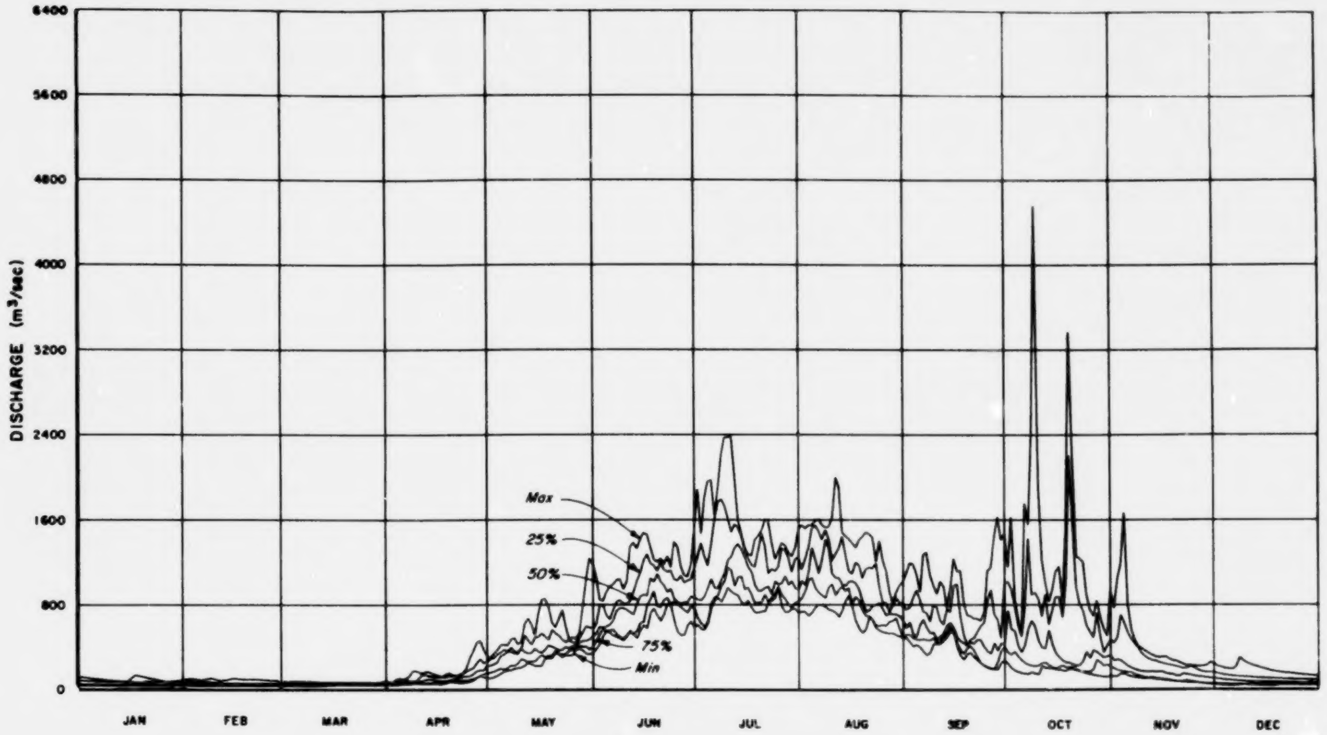
HYDROLOGY, RIVER REGIME & MORPHOLOGY
DAILY FLOW PROBABILITES - SHEET 3 OF 4

DATE AUG 1980	PLATE 4 - 3	R
DWN K.L.	DWG No. 915 - C14 - U105	



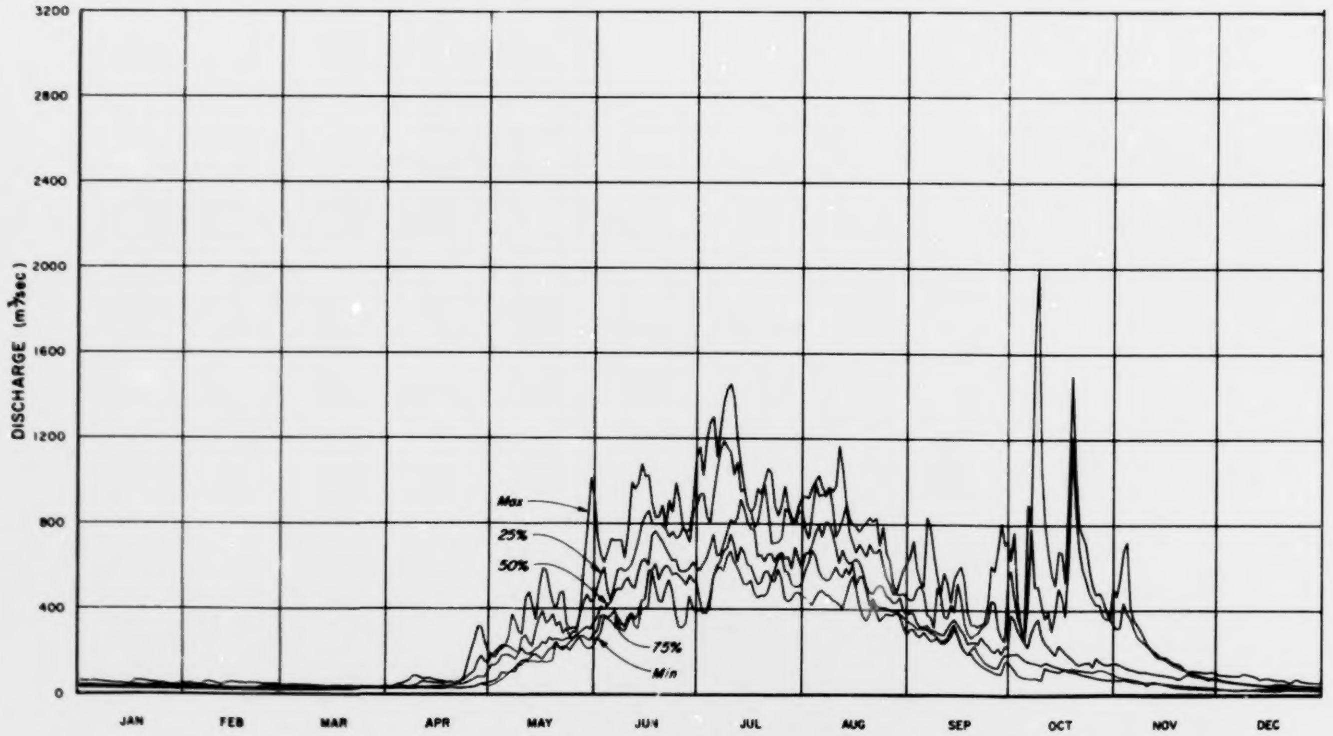
ISKUT RIVER BELOW JOHNSON RIVER

(NATURAL FLOWS 1959 - 1979)



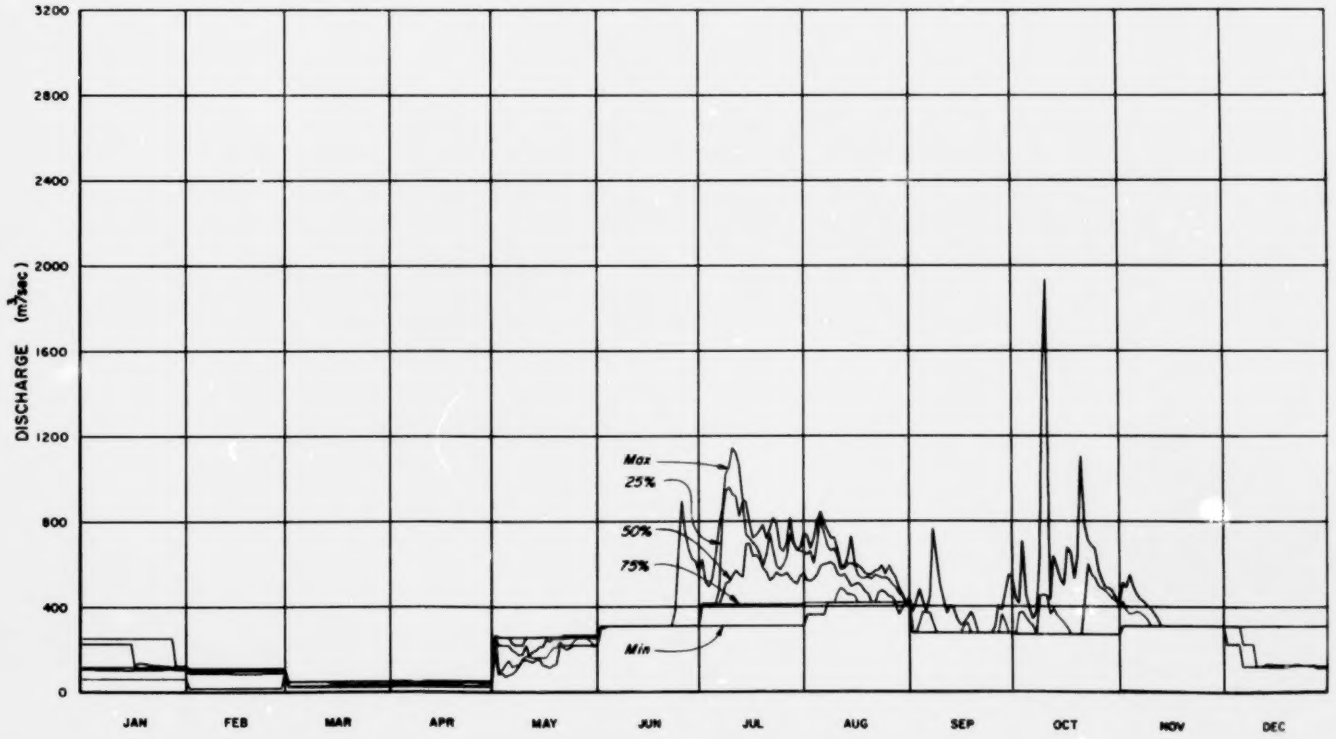
ISKUT RIVER BELOW JOHNSON RIVER

(NATURAL FLOWS 1972 - 1978)



ISKUT RIVER AT ISKUT CANYON SITE

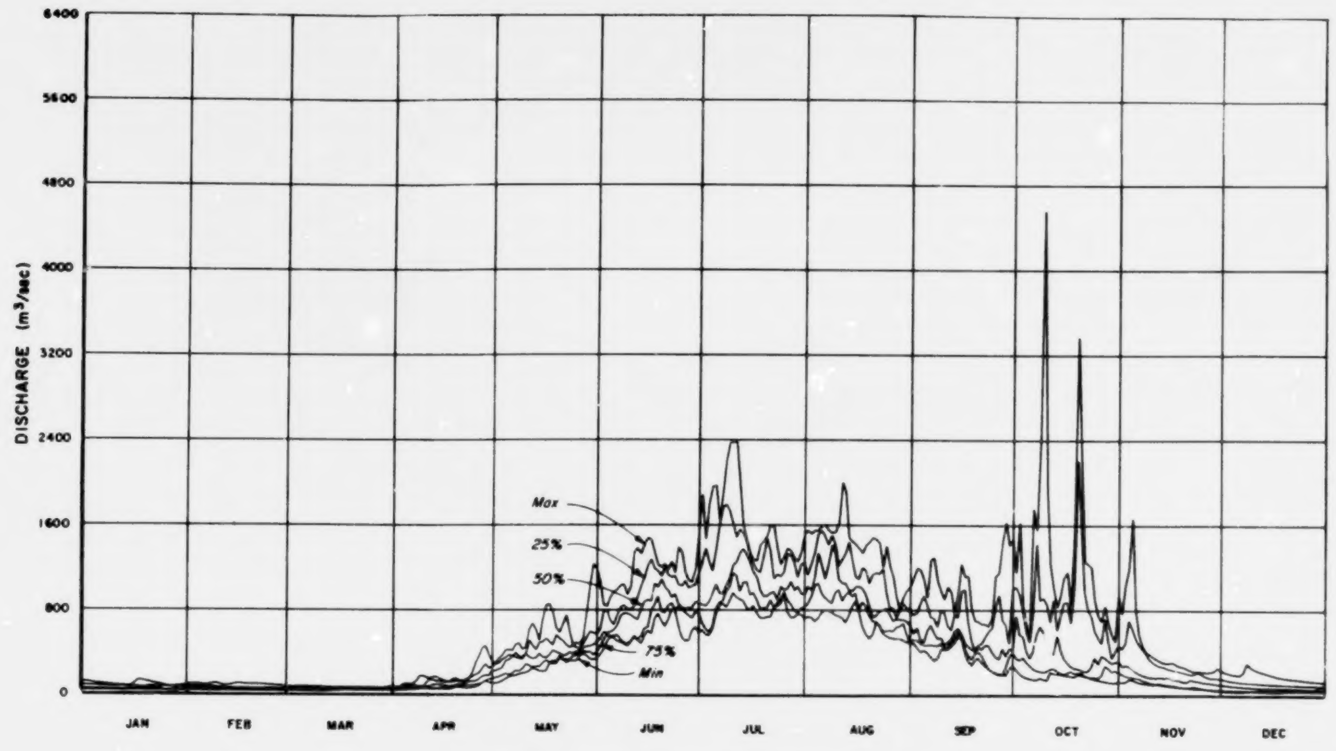
(NATURAL FLOWS 1972 - 1978)



ISKUT RIVER AT ISKUT CANYON SITE

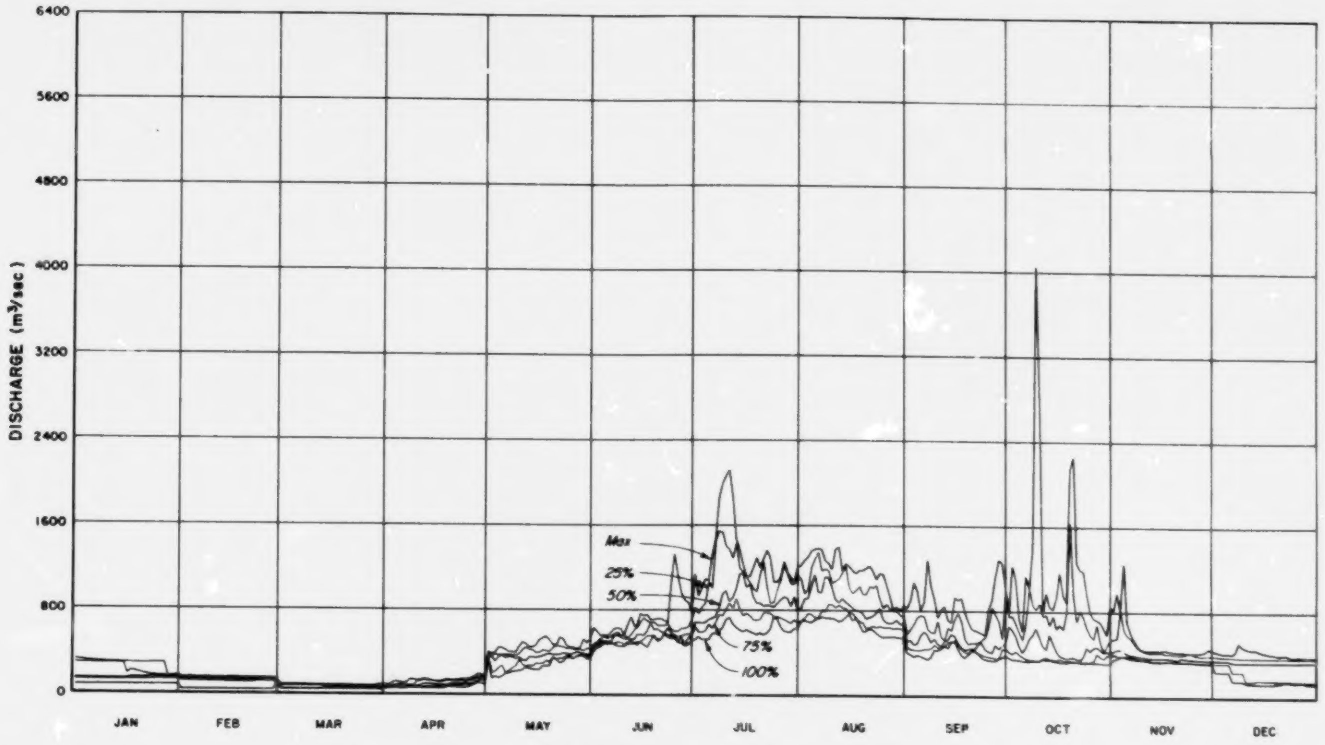
(REGULATED FLOWS 1972 - 1978)

DISCHARGE (m³/sec)



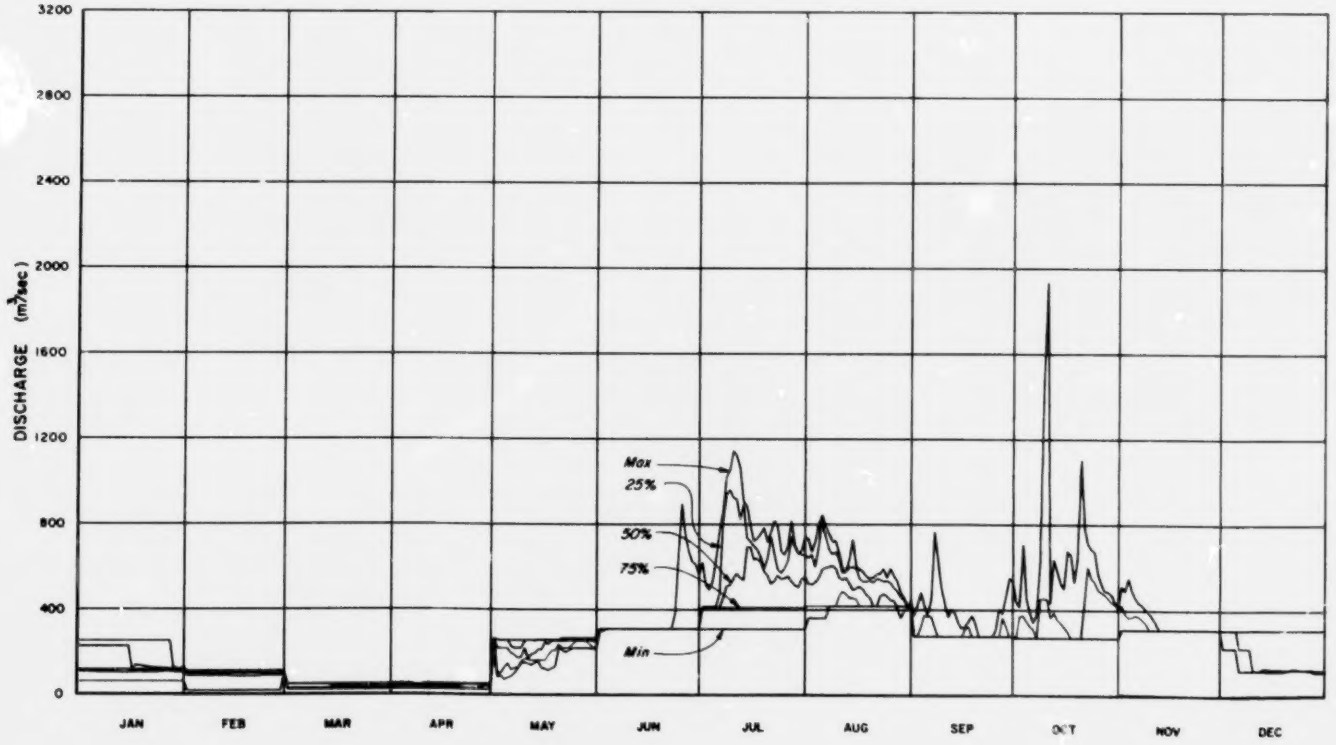
ISKUT RIVER BELOW JOHNSON RIVER

(NATURAL FLOWS 1972 - 1978)



ISKUT RIVER BELOW JOHNSON RIVER

(REGULATED FLOWS 1972 - 1978)



ISKUT RIVER AT ISKUT CANYON SITE

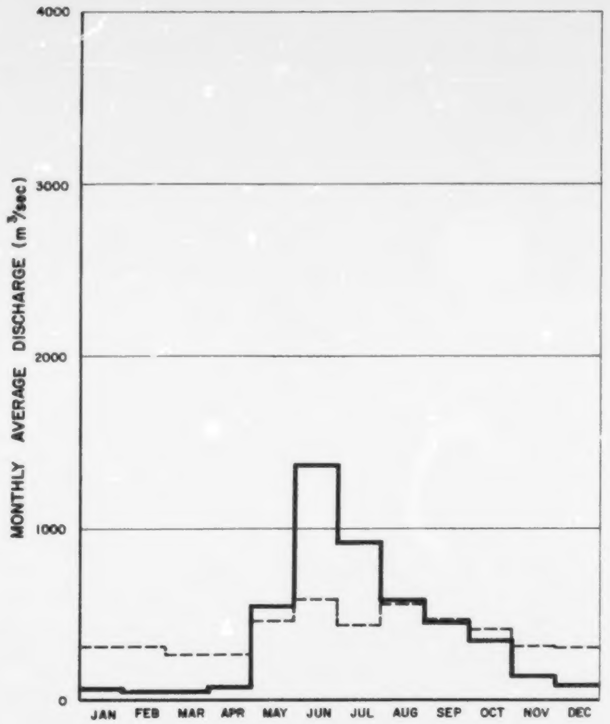
(REGULATED FLOWS 1972 - 1978)

BRITISH COLUMBIA HYDRO AND POWER AUTHORITY

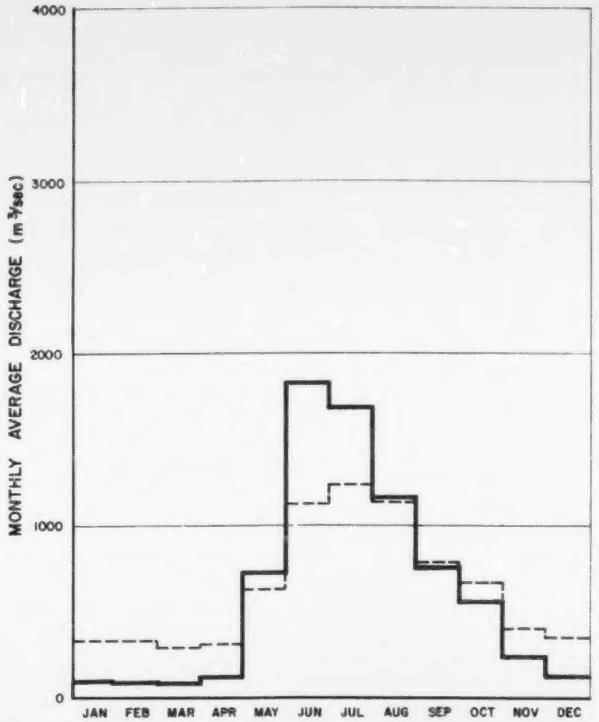
STIKINE - ISKUT FEASIBILITY STUDY

HYDROLOGY, RIVER REGIME & MORPHOLOGY
DAILY FLOW PROBABILITES - SHEET 4 OF 4

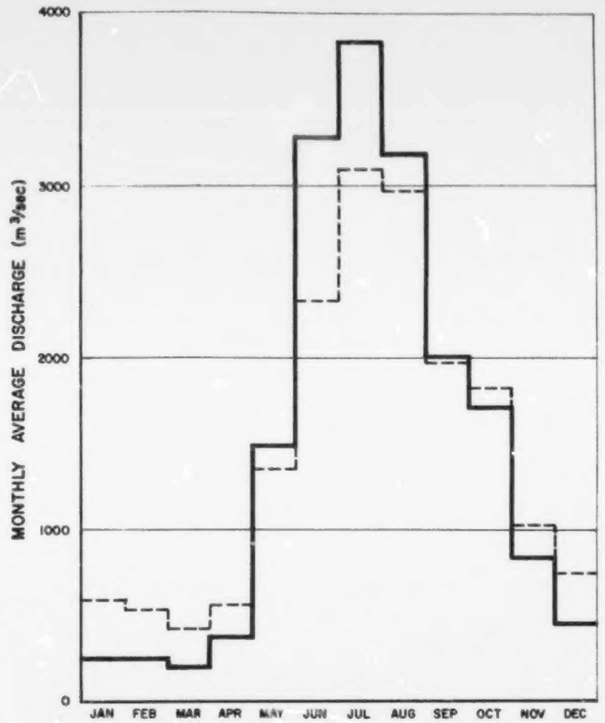
DATE AUG 1980	PLATE 4 - 3	R
DWN K.L.	DWG No. 915 - C14 - X106	



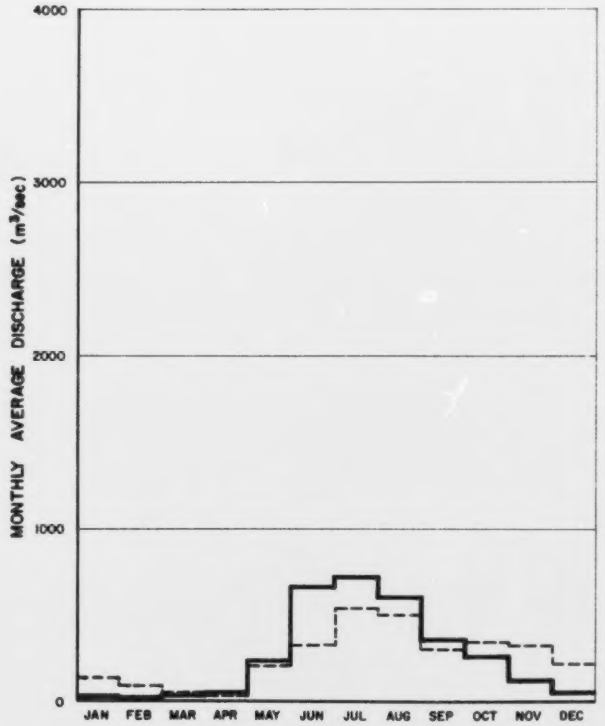
STIKINE RIVER AT TELEGRAPH CREEK
1972 - 1977



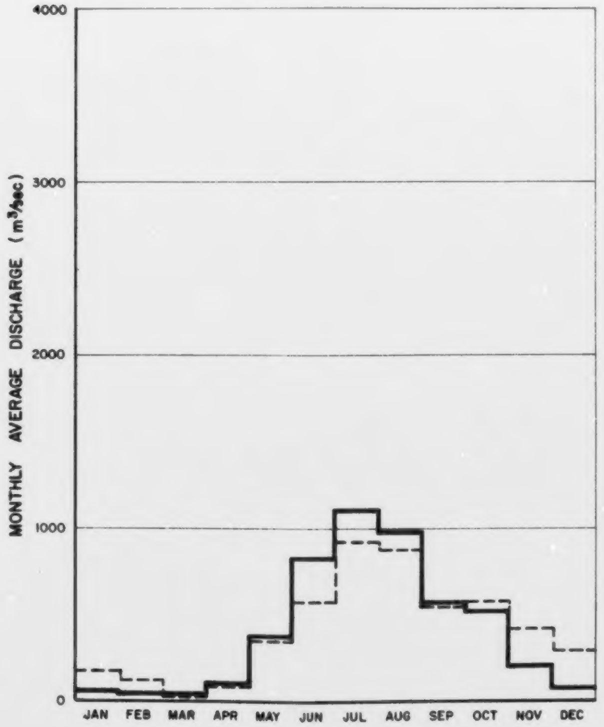
STIKINE RIVER ABOVE BUTTERFLY CREEK
1972 - 1977



STIKINE RIVER NEAR WRANGELL, ALASKA
1972 - 1977



ISKUT RIVER ABOVE SNIPPAKER CREEK
1972 - 1977



ISKUT RIVER BELOW JOHNSON RIVER
1972 - 1977

LEGEND:
—— EXISTING REGIME
- - - REGULATED REGIME

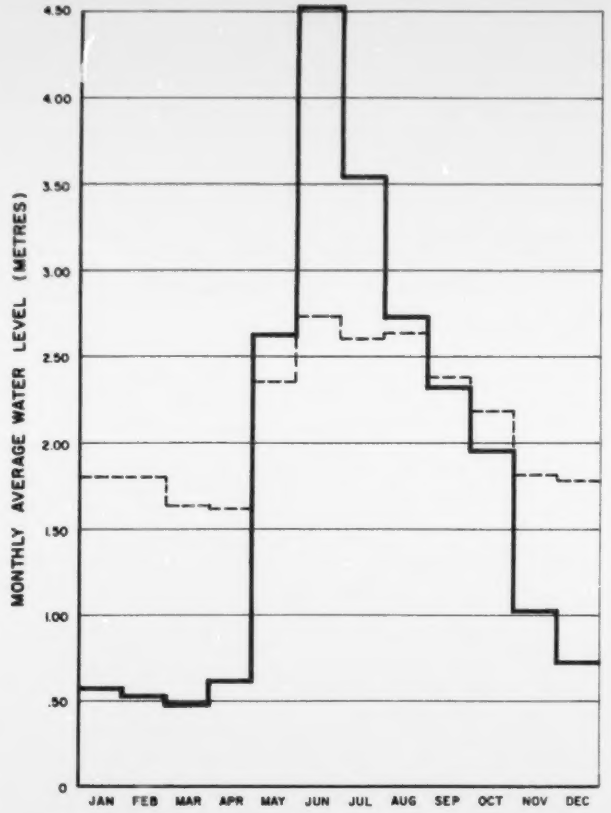
BRITISH COLUMBIA HYDRO AND POWER AUTHORITY

STIKINE - ISKUT FEASIBILITY STUDY

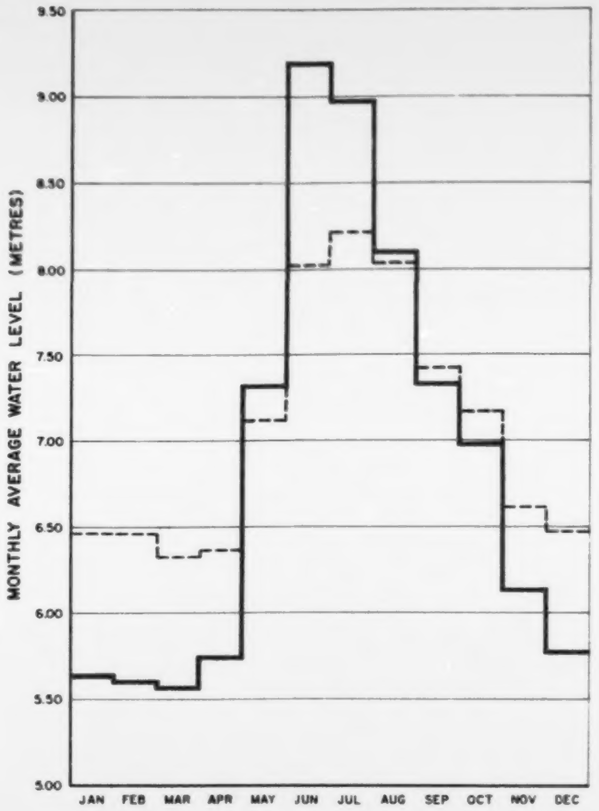
HYDROLOGY, RIVER REGIME & MORPHOLOGY
MEAN MONTHLY FLOWS

DATE AUG 1980
PLATE 4 - 4 R
DWN K.L.
DWG No. 915 - C14 - D107

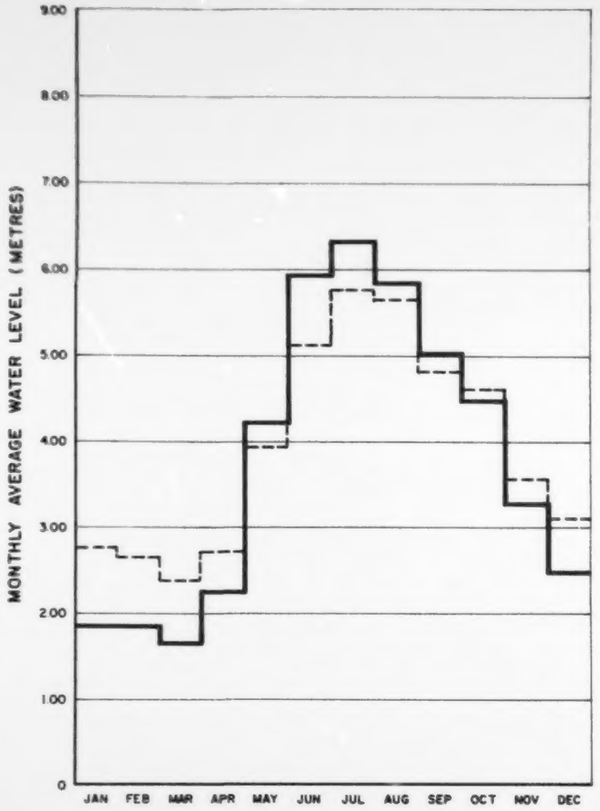
REPORT No. H-1110



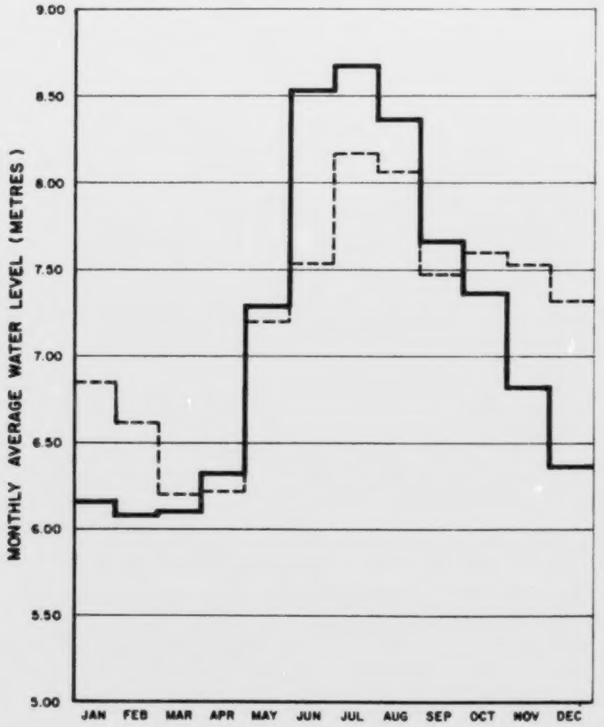
STIKINE RIVER AT TELEGRAPH CREEK
1972 - 1977



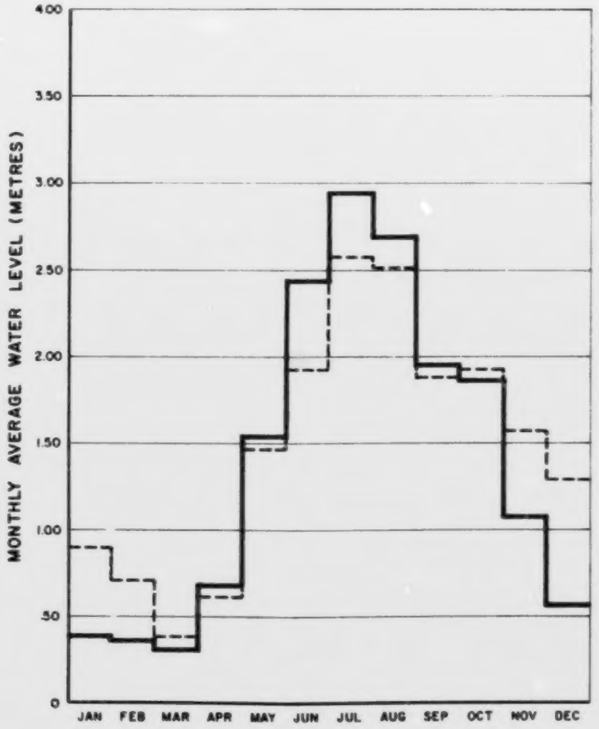
STIKINE RIVER ABOVE BUTTERFLY CREEK
1972 - 1977



STIKINE RIVER NEAR WRANGELL, ALASKA
1972 - 1977



ISKUT RIVER ABOVE SNIPPAKER CREEK
1972 - 1977



ISKUT RIVER BELOW JOHNSON RIVER
1972 - 1977

LEGEND:
— EXISTING REGIME
- - - REGULATED REGIME

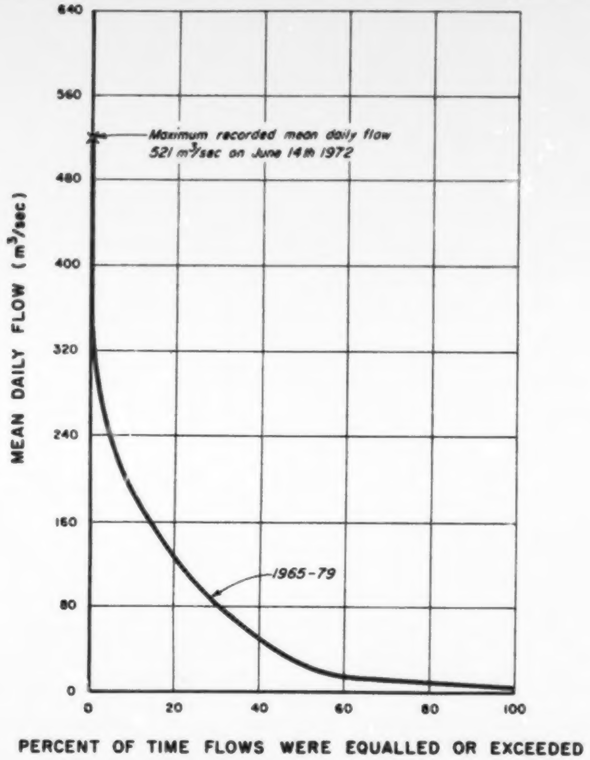
BRITISH COLUMBIA HYDRO AND POWER AUTHORITY

STIKINE - ISKUT FEASIBILITY STUDY

HYDROLOGY, RIVER REGIME & MORPHOLOGY
MEAN MONTHLY WATER LEVELS

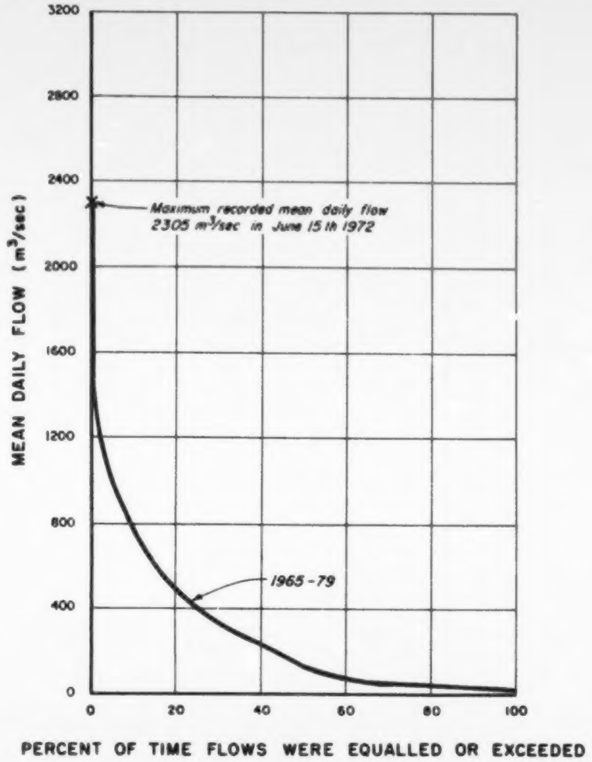
DATE AUG 1980
PLATE 4 - 5 R
DWN K.L.
DWG No. 915 - C14 - D108

REPORT No. H-1110



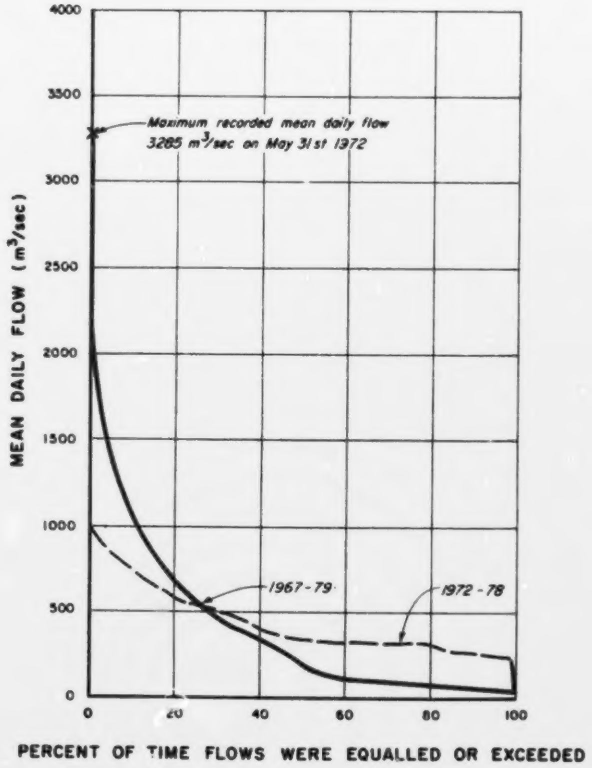
KLAPPAN RIVER NEAR TELEGRAPH CREEK

DRAINAGE AREA 3550 km^2



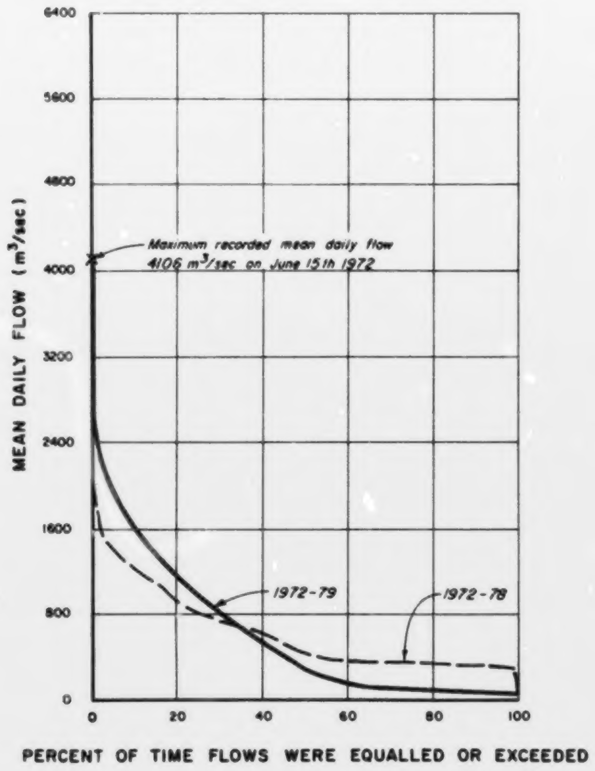
STIKINE RIVER ABOVE GRAND CANYON

DRAINAGE AREA 18800 km^2



STIKINE RIVER AT TELEGRAPH CREEK

DRAINAGE AREA 34400 km^2



STIKINE RIVER ABOVE BUTTERFLY CREEK

DRAINAGE AREA 36000 km^2

NOTE:

━━	NATURAL CONDITIONS
— —	REGULATED CONDITIONS

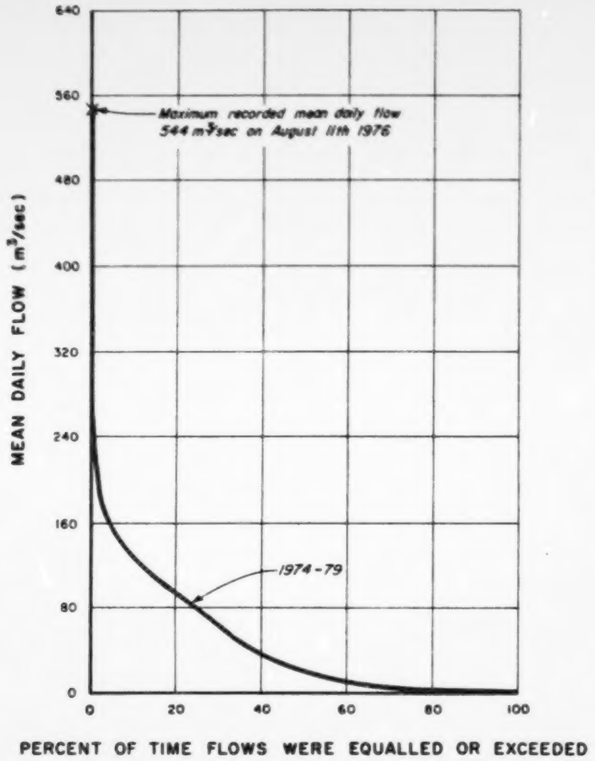
BRITISH COLUMBIA HYDRO AND POWER AUTHORITY

STIKINE - ISKUT FEASIBILITY STUDY

HYDROLOGY, RIVER REGIME MORPHOLOGY
FLOW DURATION CURVES -SHEET 1 OF 2

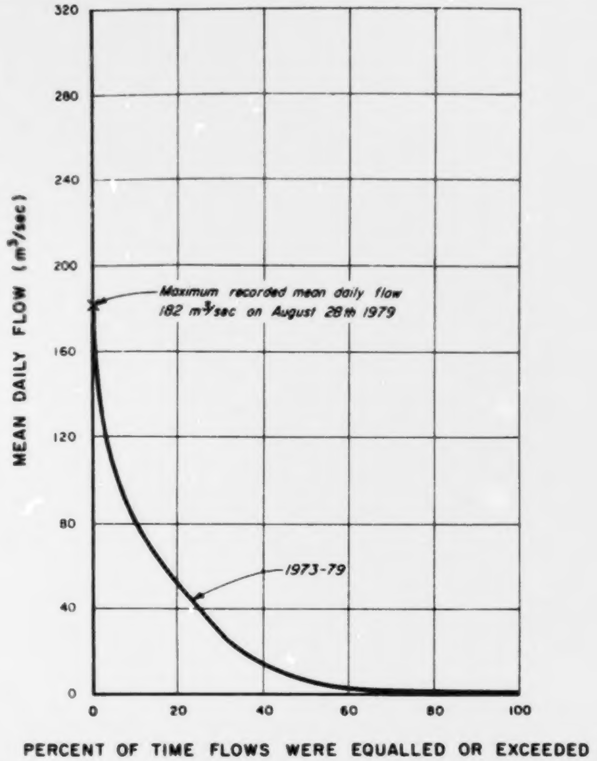
DATE AUG 1980	PLATE 4-6	R
DWN K.L.	DWG No. 915-C14-D109	

REPORT No. H-1110



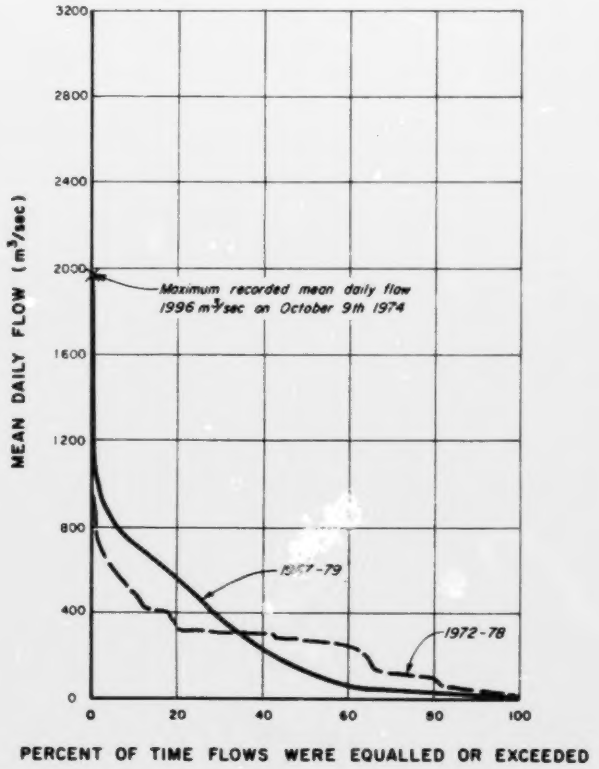
MORE CREEK NEAR THE MOUTH

DRAINAGE AREA 787 km^2



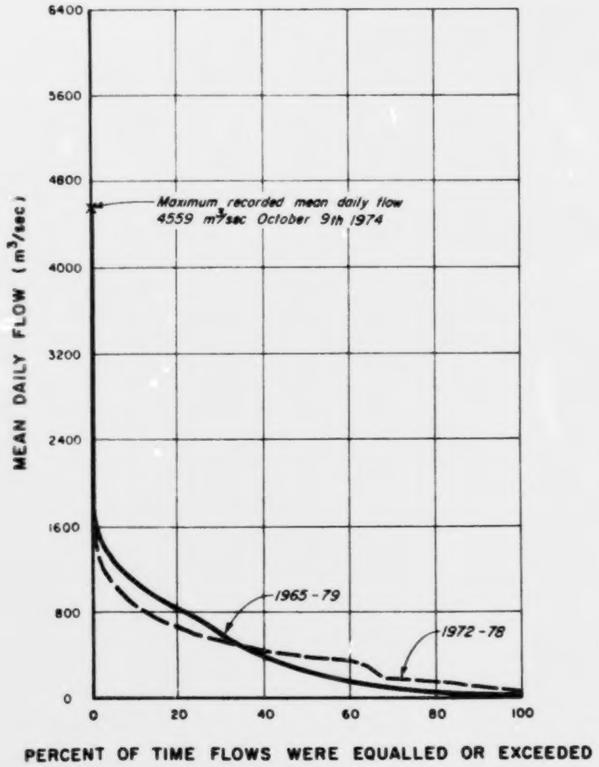
FORREST KERR CREEK ABOVE 460 METRE CONTOUR

DRAINAGE AREA 311 km^2



ISKUT RIVER ABOVE SNIPPAKER CREEK

DRAINAGE AREA 7230 km^2



ISKUT RIVER BELOW JOHNSON RIVER

DRAINAGE AREA 9350 km^2

NOTE.

━━	NATURAL CONDITIONS
— —	REGULATED CONDITIONS

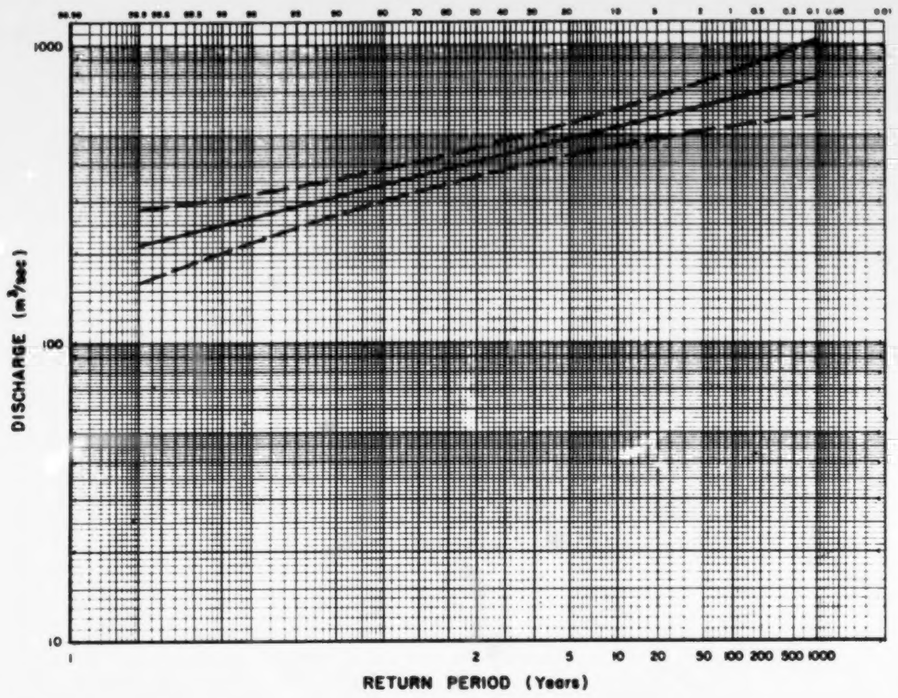
BRITISH COLUMBIA HYDRO AND POWER AUTHORITY

STIKINE - ISKUT FEASIBILITY STUDY

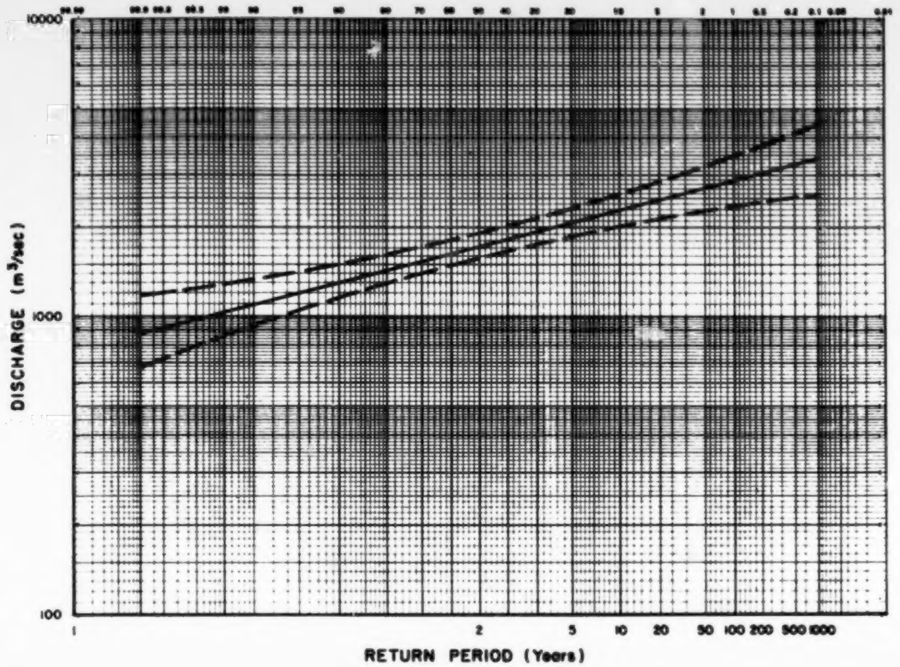
HYDROLOGY, RIVER REGIME MORPHOLOGY
FLOW DURATION CURVES - SHEET 2 OF 2

DATE AUG 1980	PLATE 4 - 6	R
DWN K.L.	DWG No. 915 - C14 - D110	

REPORT No. H - 1110

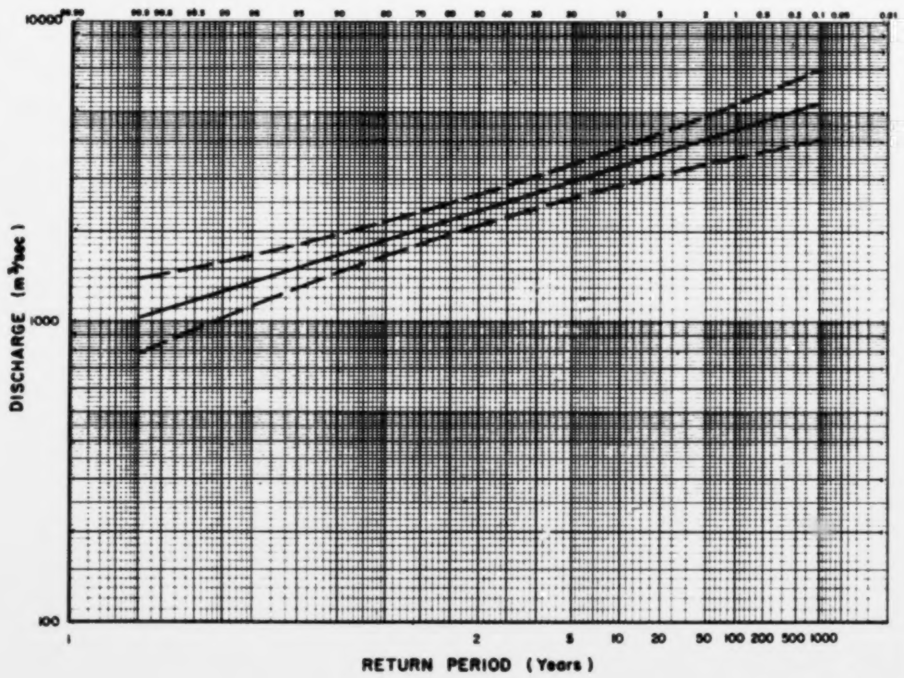


KLAPPAN RIVER NEAR TELEGRAPH CREEK
(Annual maximum daily discharges 1963 - 1978)

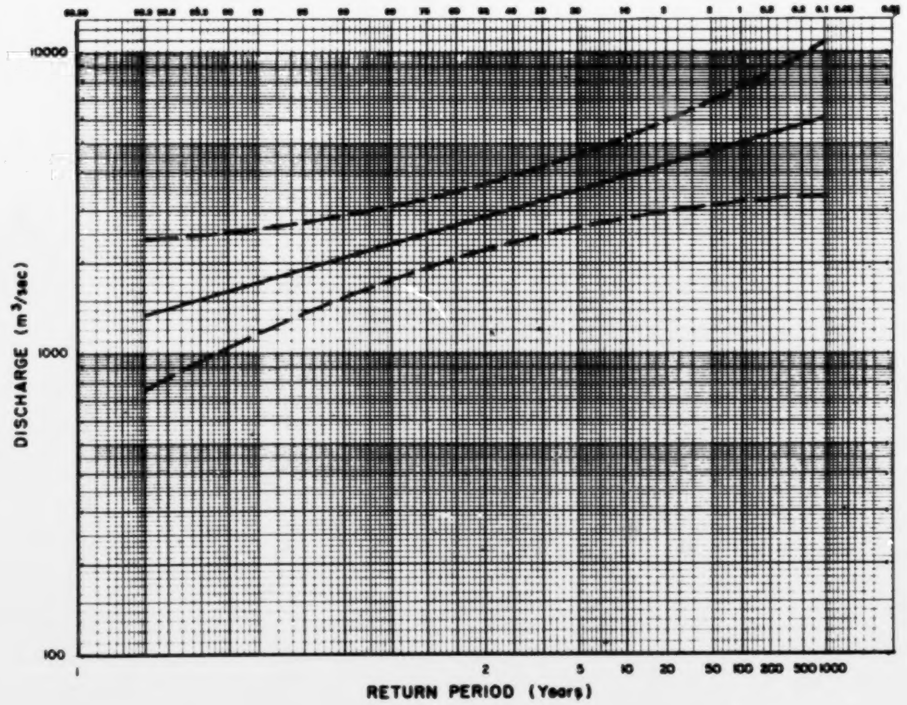


STIKINE RIVER ABOVE GRAND CANYON
(Annual maximum daily discharges 1958 - 1978)

LEGEND
— — 95% CONFIDENCE LIMITS



STIKINE RIVER AT TELEGRAPH CREEK
(Annual maximum daily discharges 1955 - 1978)



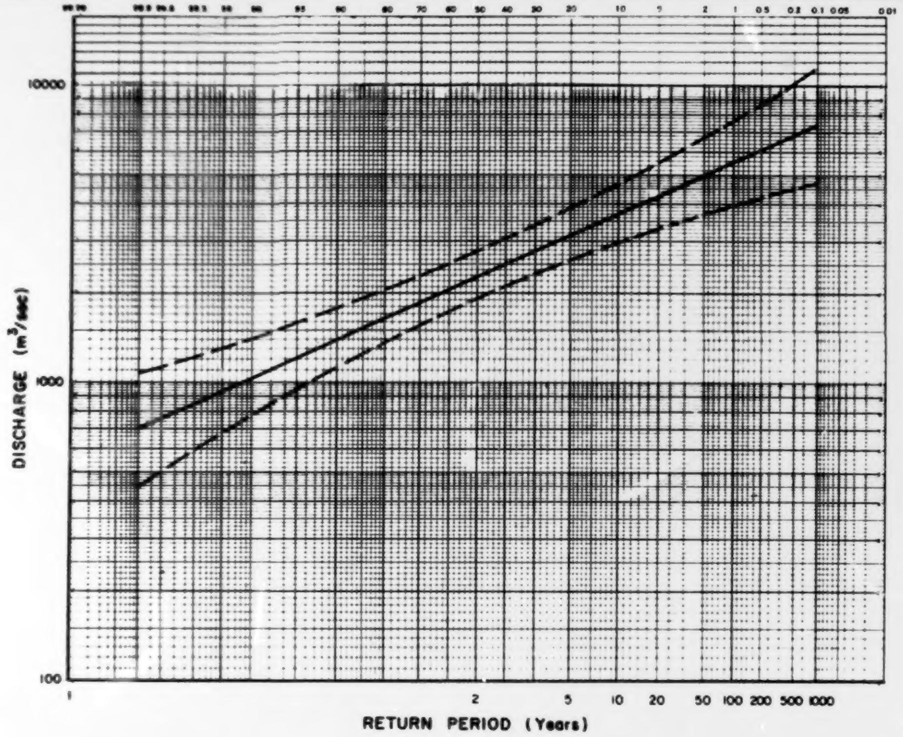
STIKINE RIVER ABOVE BUTTERFLY CREEK
(Annual maximum daily discharges 1972 - 1978)

BRITISH COLUMBIA HYDRO AND POWER AUTHORITY

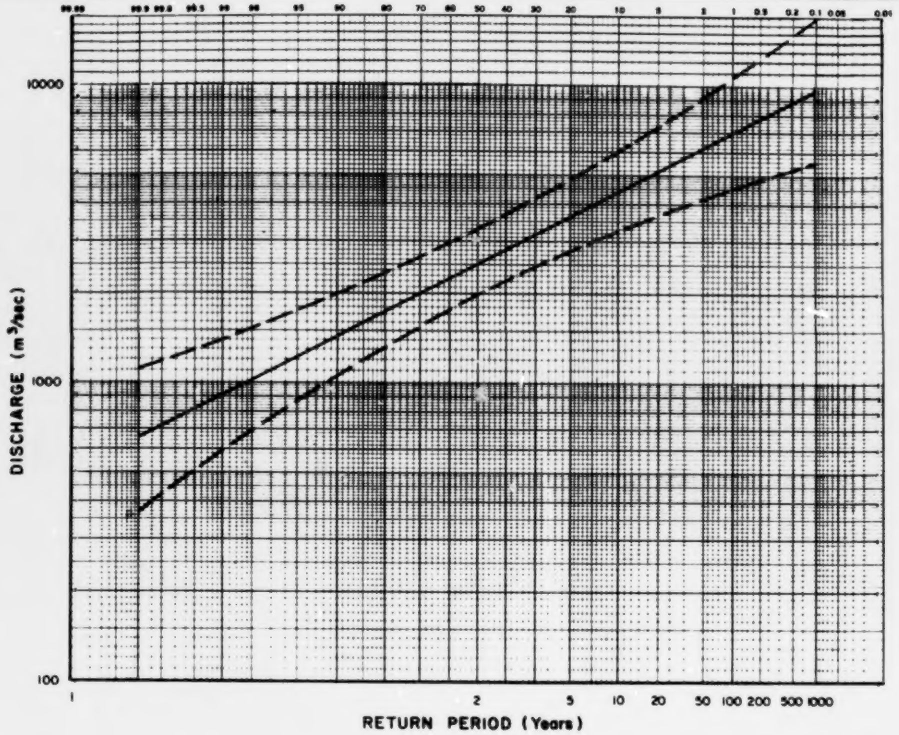
STIKINE - ISKUT FEASIBILITY STUDY
HYDROLOGY, RIVER REGIME & MORPHOLOGY
FLOOD FREQUENCY CURVES
-SHEET 1 OF 4

DATE	AUG 1980	PLATE 4-7	R
DWN	K.L.	DWG No. 915-C14-D111	

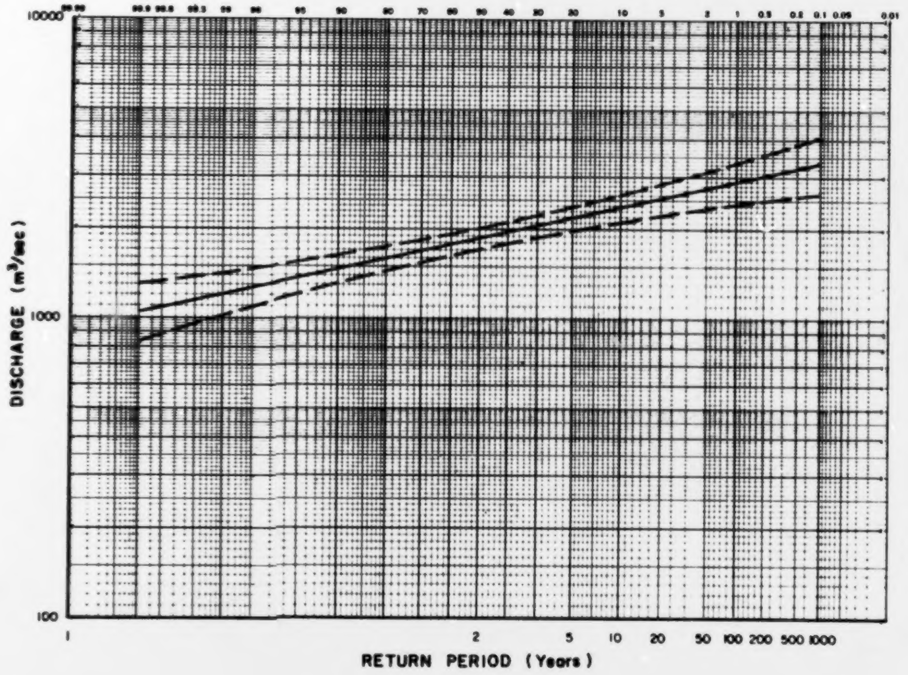
REPORT No. H-1110



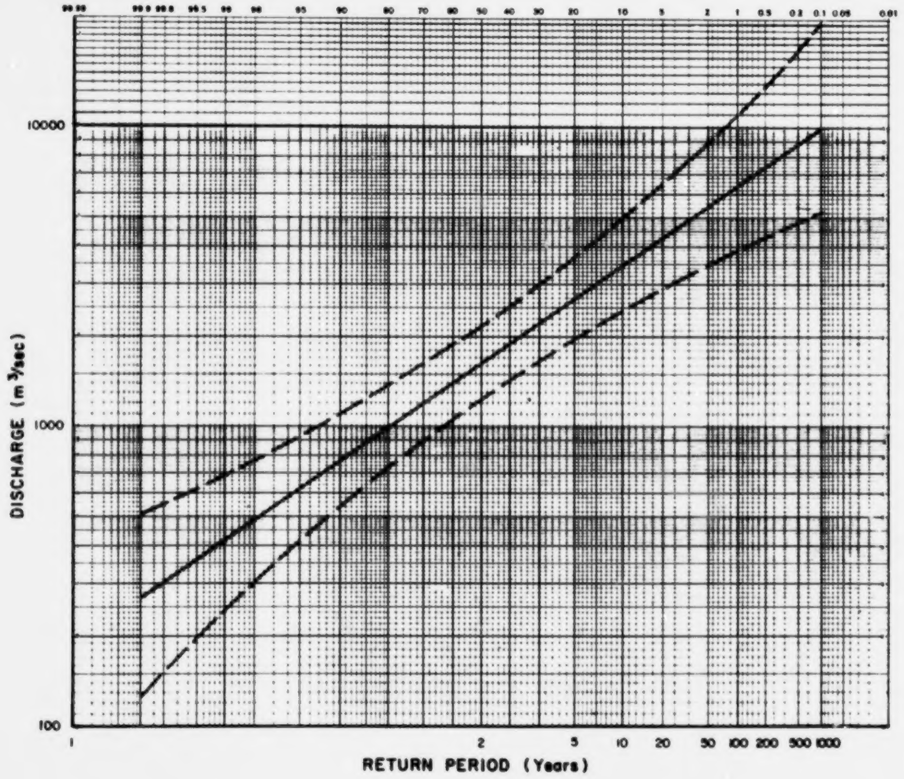
ISKUT RIVER BELOW JOHNSON RIVER
(Annual maximum daily discharges 1959 - 1978)



ISKUT RIVER BELOW JOHNSON RIVER
(Annual maximum instantaneous discharges 1959 - 1978)



ISKUT RIVER BELOW JOHNSON RIVER
(Seasonal maximum daily discharges 1959 - 1978)
June - August



ISKUT RIVER BELOW JOHNSON RIVER
(Seasonal maximum daily discharges 1959 - 1978)
September - November

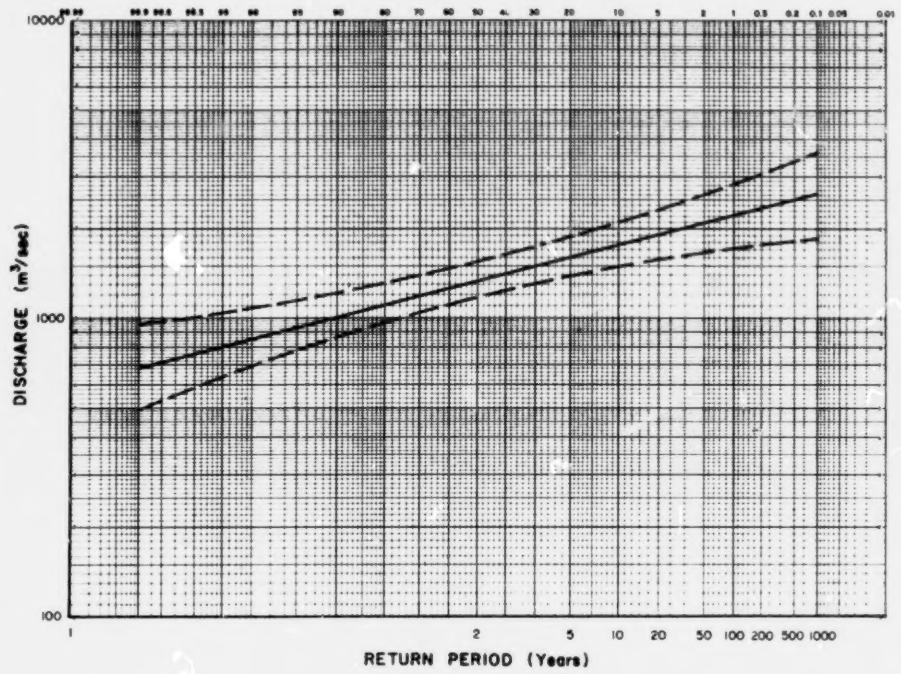
LEGEND
— — 95% CONFIDENCE LIMITS

BRITISH COLUMBIA HYDRO AND POWER AUTHORITY

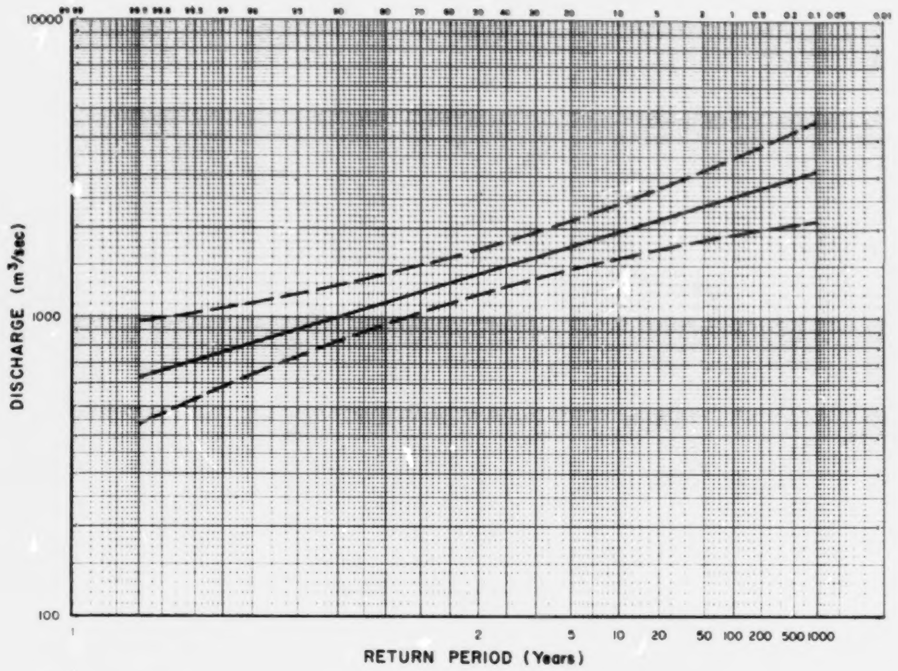
STIKINE - ISKUT FEASIBILITY STUDY
HYDROLOGY, RIVER REGIME & MORPHOLOGY
FLOOD FREQUENCY CURVES
-SHEET 2 OF 4

DATE	AUG 1980	PLATE 4-7	R
DWN	K.L.	DWG No. 915 - C14 - D112	

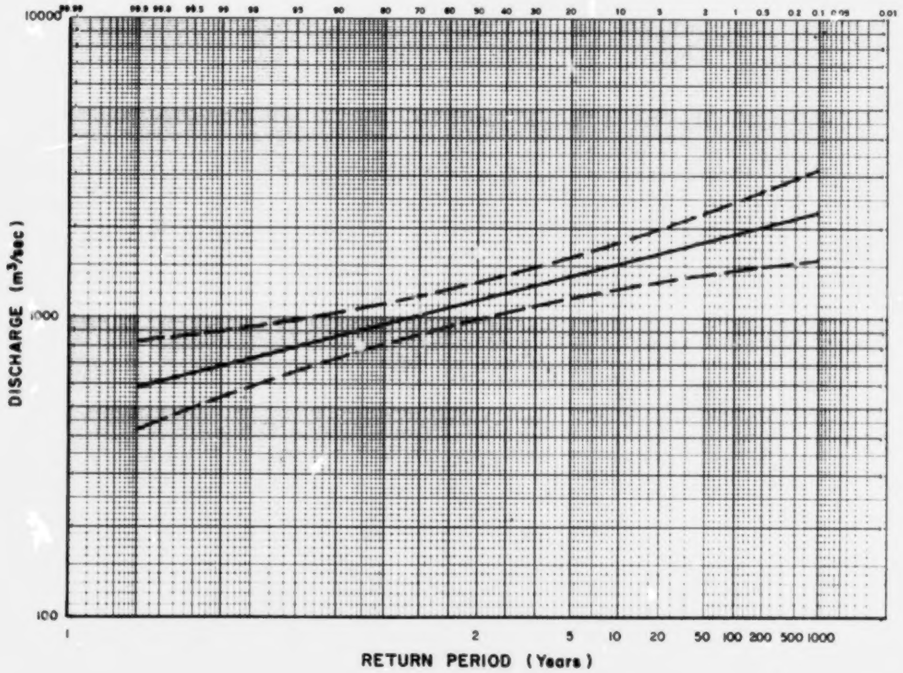
REPORT No. H-1110



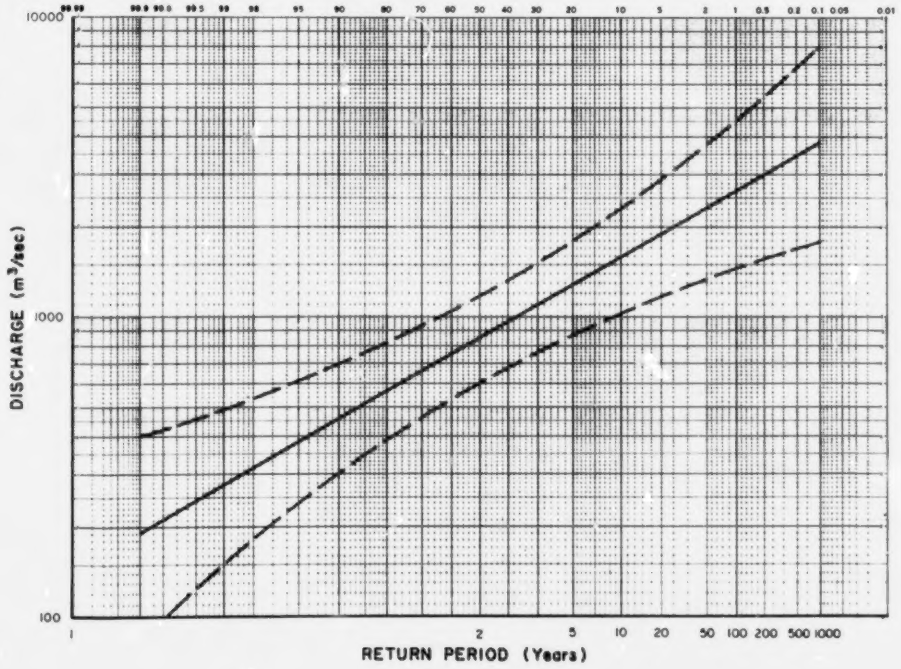
ISKUT RIVER ABOVE SNIPPAKER CREEK
(Annual maximum daily discharges 1967 - 1978)



ISKUT RIVER ABOVE SNIPPAKER CREEK
(Annual maximum instantaneous discharges 1967 - 1978)



ISKUT RIVER ABOVE SNIPPAKER CREEK
(Seasonal maximum daily discharges 1967 - 1978)
June - August



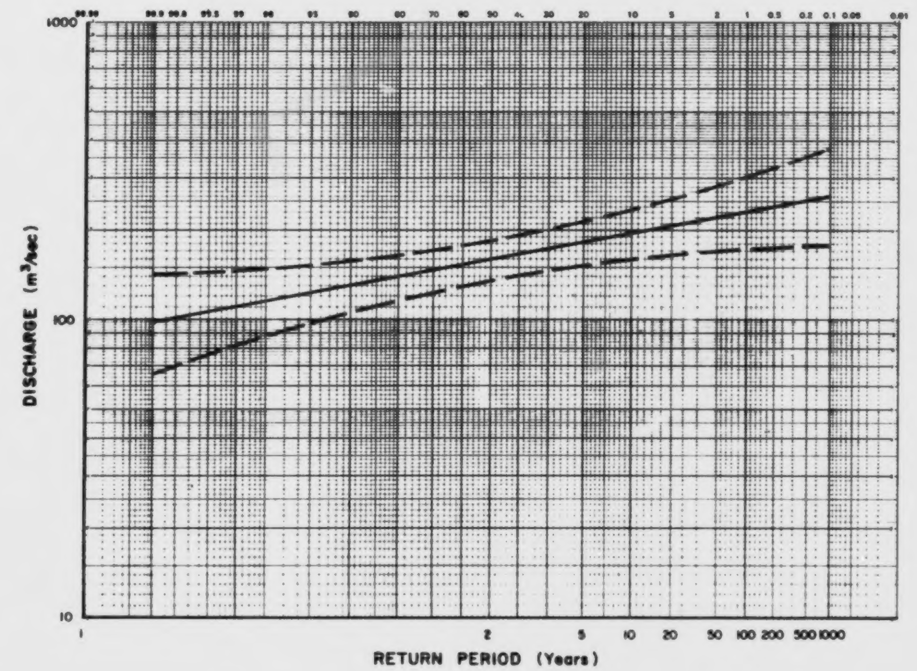
ISKUT RIVER ABOVE SNIPPAKER CREEK
(Seasonal maximum daily discharges 1967 - 1978)
September - November

LEGEND
— — 95% CONFIDENCE LIMITS

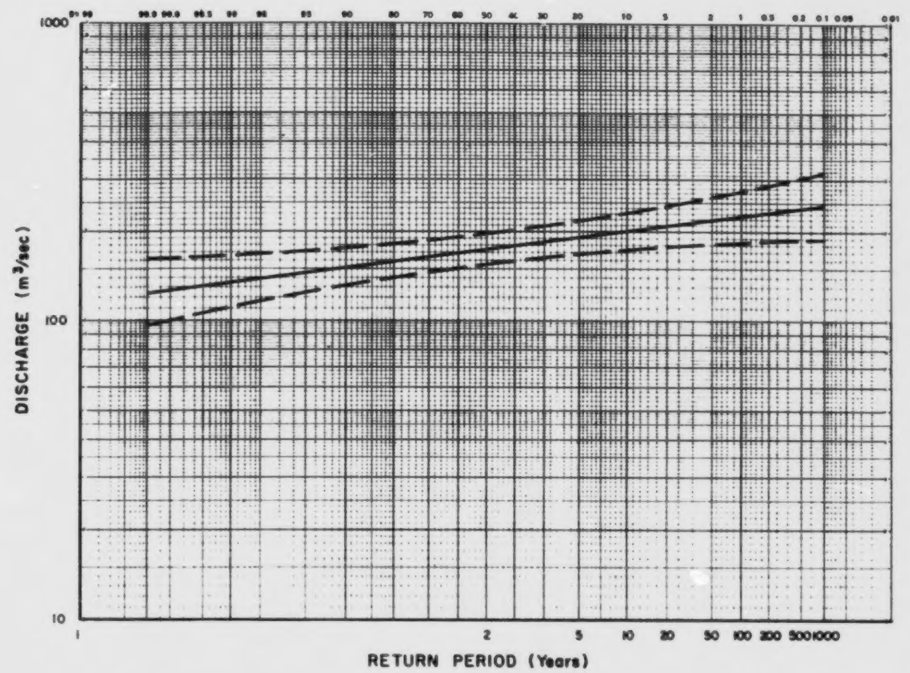
BRITISH COLUMBIA HYDRO AND POWER AUTHORITY

STIKINE - ISKUT FEASIBILITY STUDY
HYDROLOGY, RIVER REGIME & MORPHOLOGY
FLOOD FREQUENCY CURVES
-SHEET 3 OF 4

DATE AUG 1980
PLATE 4 -7 R
DWN K.L.
DWG No. 915 - C14 - D113
REPORT No. H-1110



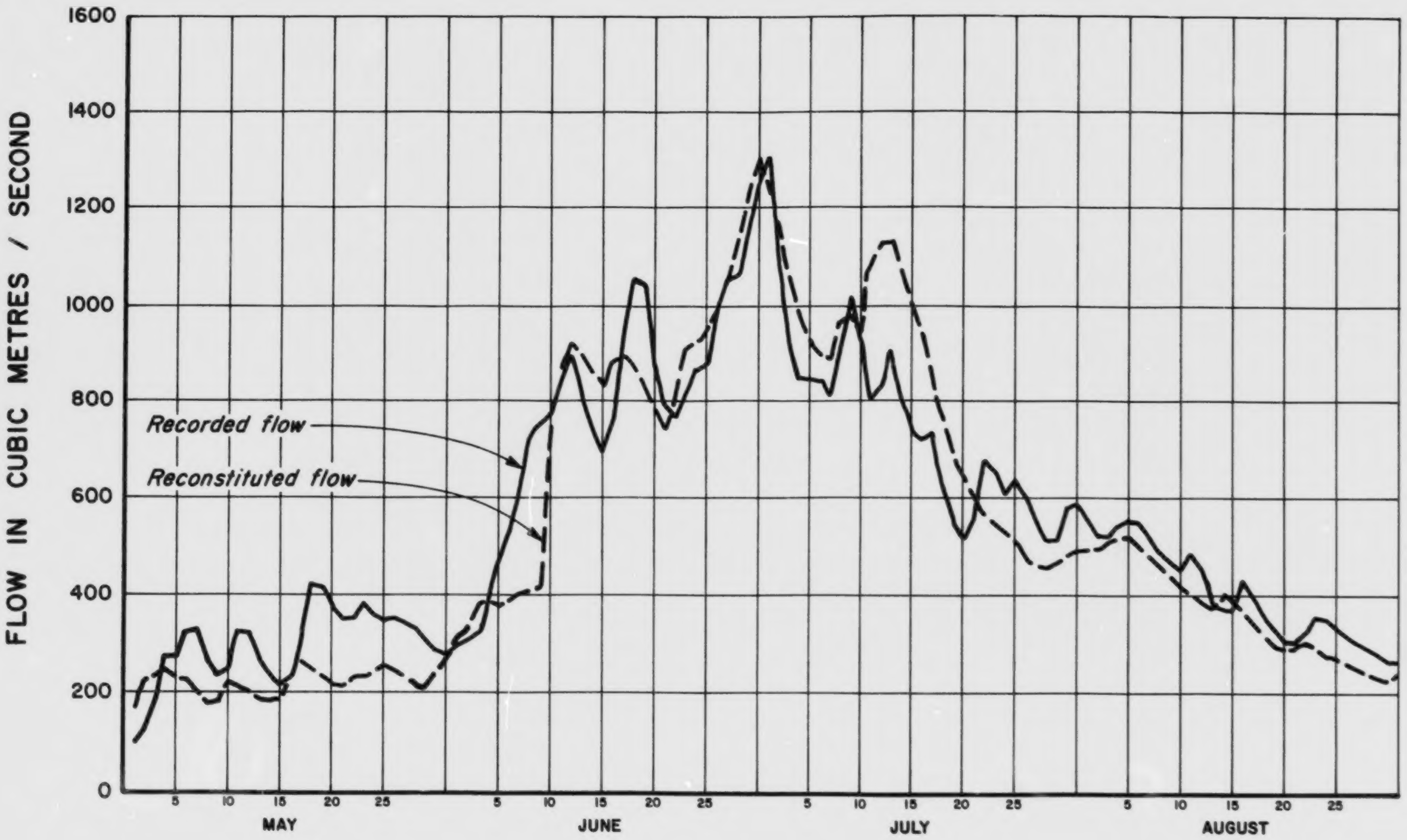
FORREST KERR CREEK ABOVE 460 METRE CONTOUR
(Annual maximum daily discharges 1972 - 1978)



FORREST KERR CREEK ABOVE 460 METRE CONTOUR
(Annual maximum instantaneous discharge 1972 - 1978)

BRITISH COLUMBIA HYDRO AND POWER AUTHORITY		
STIKINE - ISKUT FEASIBILITY STUDY HYDROLOGY, RIVER REGIME & MORPHOLOGY FLOOD FREQUENCY CURVES -SHEET 4 OF 4		
DATE AUG 1980	PLATE 4-7	R
DWN K.L.	DWG No. 915-C14-D114	

REPORT No. H-1110



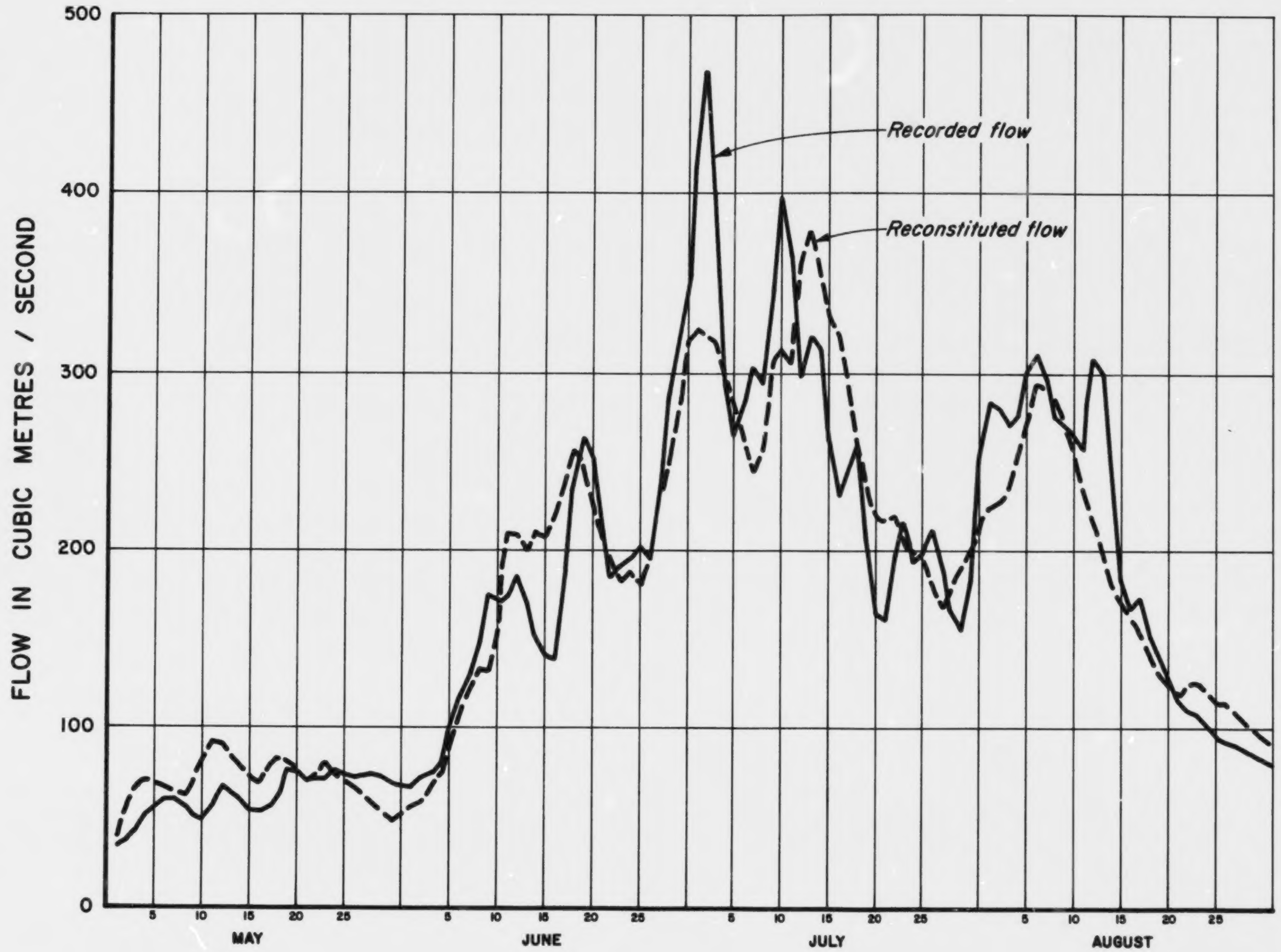
STIKINE RIVER ABOVE KLAPPAN RIVER

BRITISH COLUMBIA HYDRO AND POWER AUTHORITY

STIKINE - ISKUT FEASIBILITY STUDY
HYDROLOGY, RIVER REGIME & MORPHOLOGY
UBC WATERSHED MODEL
CALIBRATION PLOT - SHEET 1 OF 2

DATE AUG 1980	**PLATE 4 - 8**
DWN KL	DWG. No 915 - C14 - B115

REPORT No H-1110



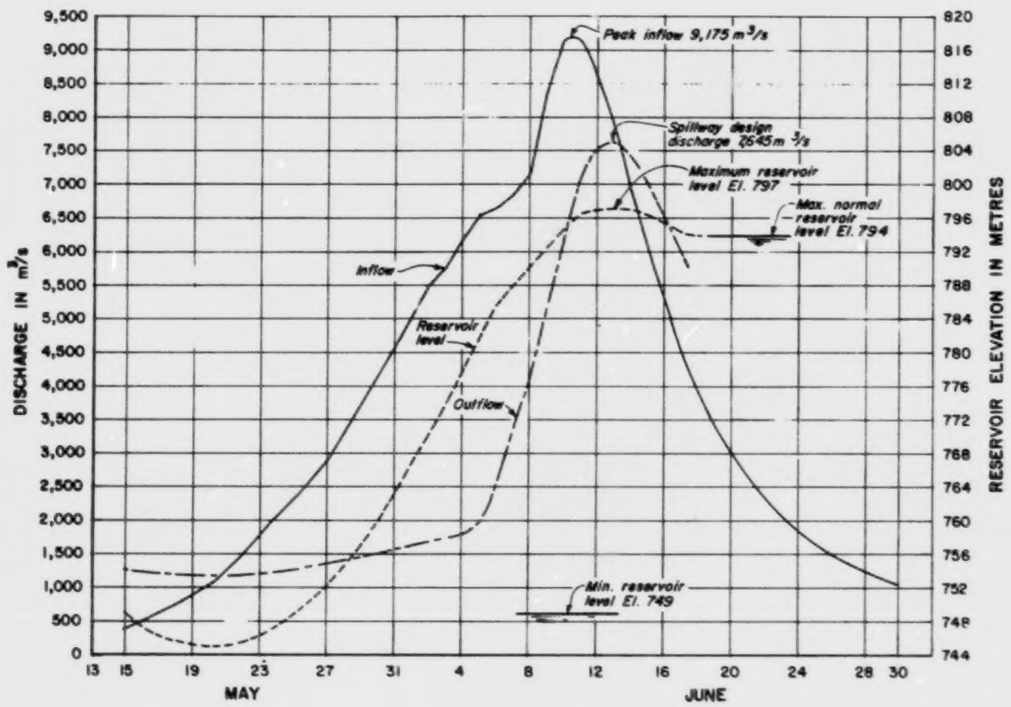
KLAPPAN RIVER

BRITISH COLUMBIA HYDRO AND POWER AUTHORITY

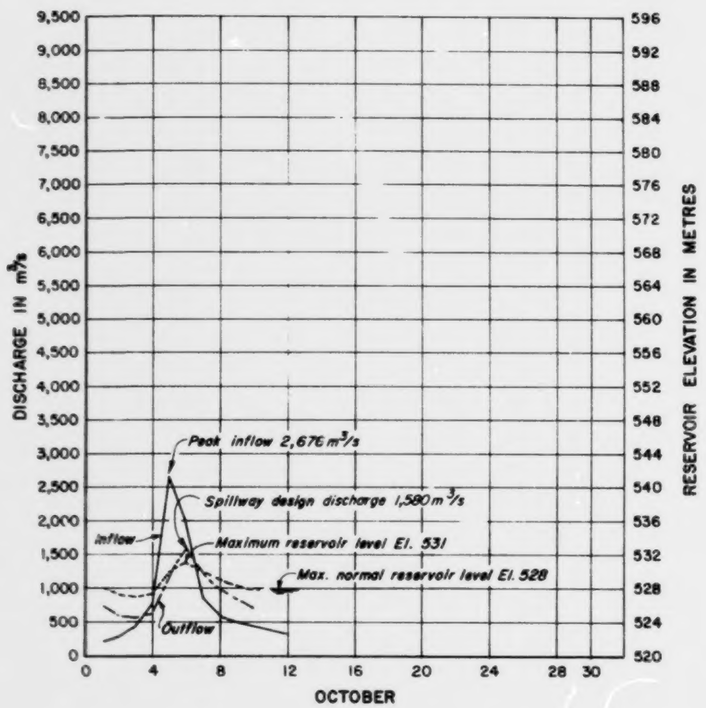
STIKINE - ISKUT FEASIBILITY STUDY
HYDROLOGY, RIVER REGIME & MORPHOLOGY
UBC WATERSHED MODEL
CALIBRATION PLOT - SHEET 2 OF 2

DATE AUG 1980	**PLATE 4 - 8**
DWN AV	DWG. No. 915 - C14 - B116

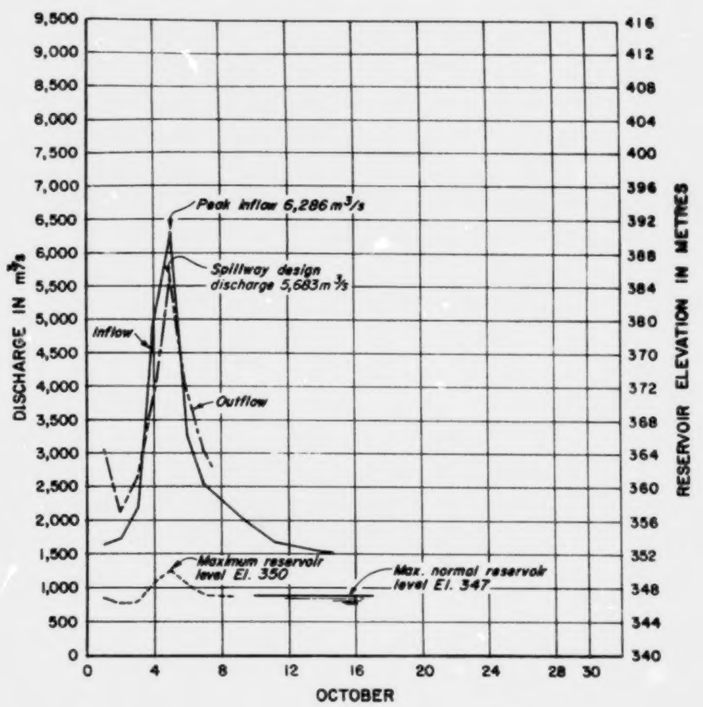
REPORT No. H-1110



STIKINE RIVER SITE Z PROJECT
PROBABLE MAXIMUM FLOOD INFLOW AND ROUTED OUTFLOW



MORE CREEK PROJECT
PROBABLE MAXIMUM FLOOD INFLOW AND ROUTED OUTFLOW



ISKUT CANYON PROJECT
PROBABLE MAXIMUM FLOOD INFLOW AND ROUTED OUTFLOW

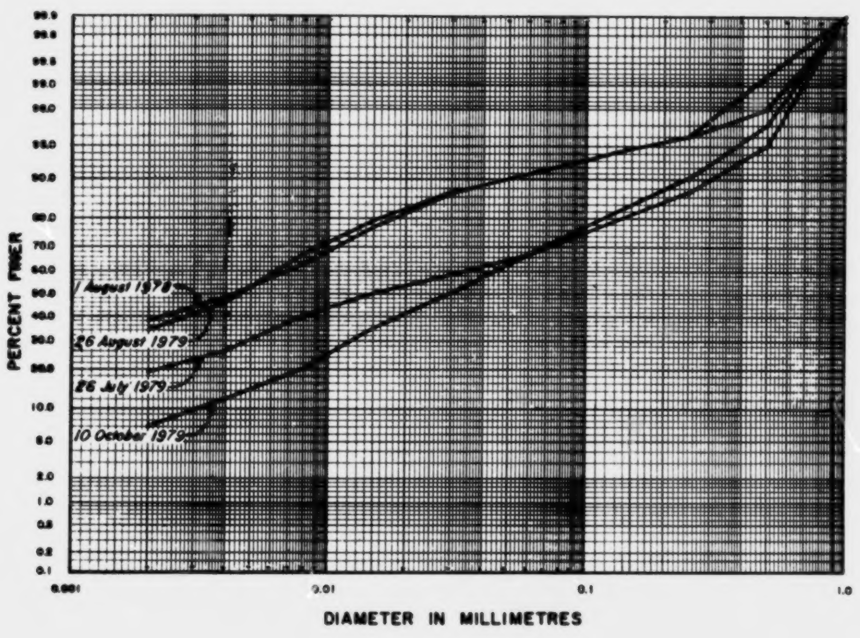
BRITISH COLUMBIA HYDRO AND POWER AUTHORITY

STIKINE - ISKUT FEASIBILITY STUDY

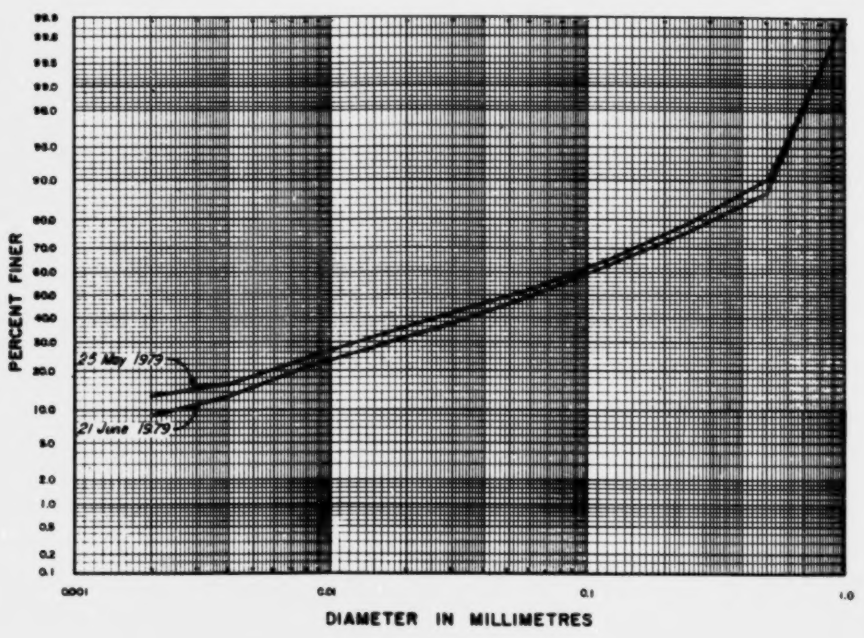
HYDROLOGY, RIVER REGIME & MORPHOLOGY
PROBABLE MAXIMUM FLOOD HYDROGRAPHS

DATE AUG 1980	PLATE 4 - 9 R
DWN K.L.	DWG No. 915 - C14 - D117

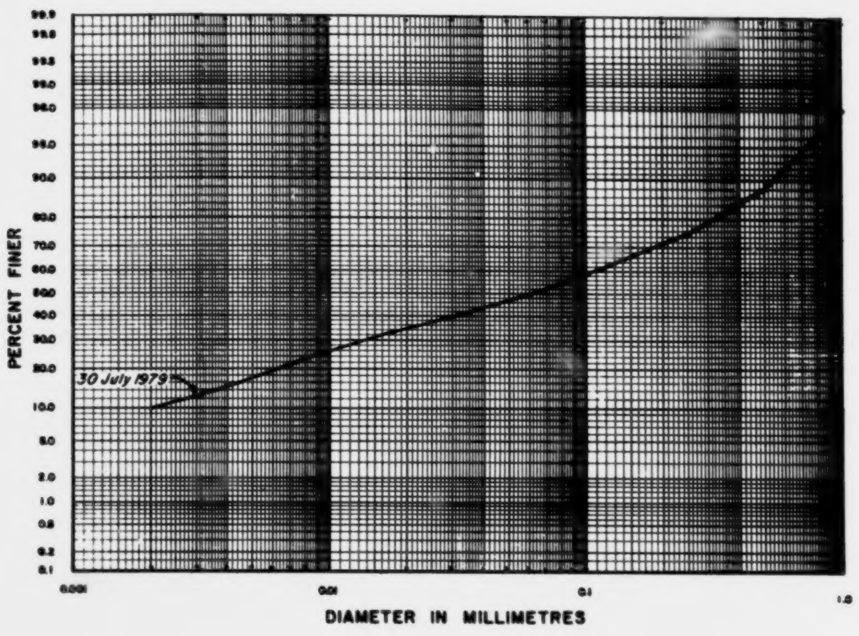
REPORT No. H-1110



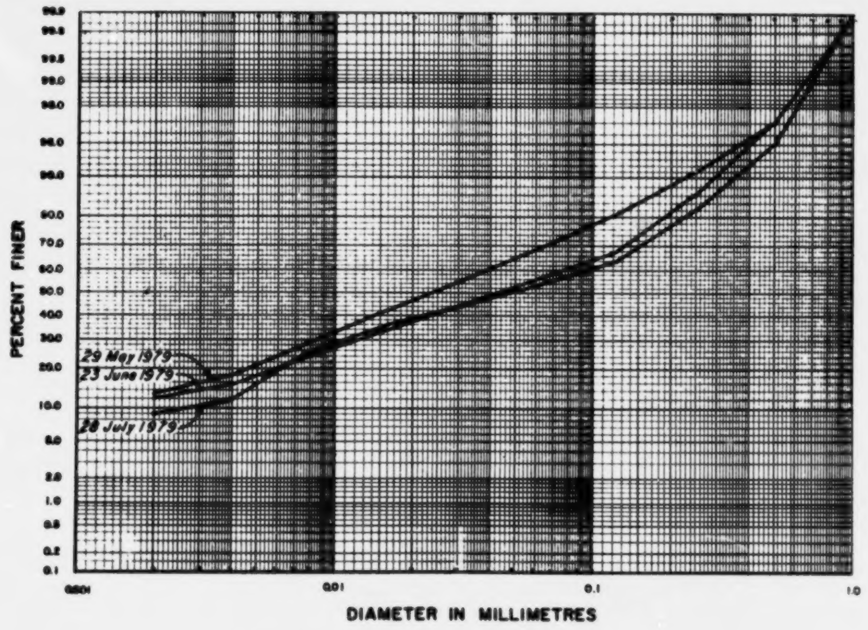
KLAPPAN RIVER NEAR TELEGRAPH CREEK



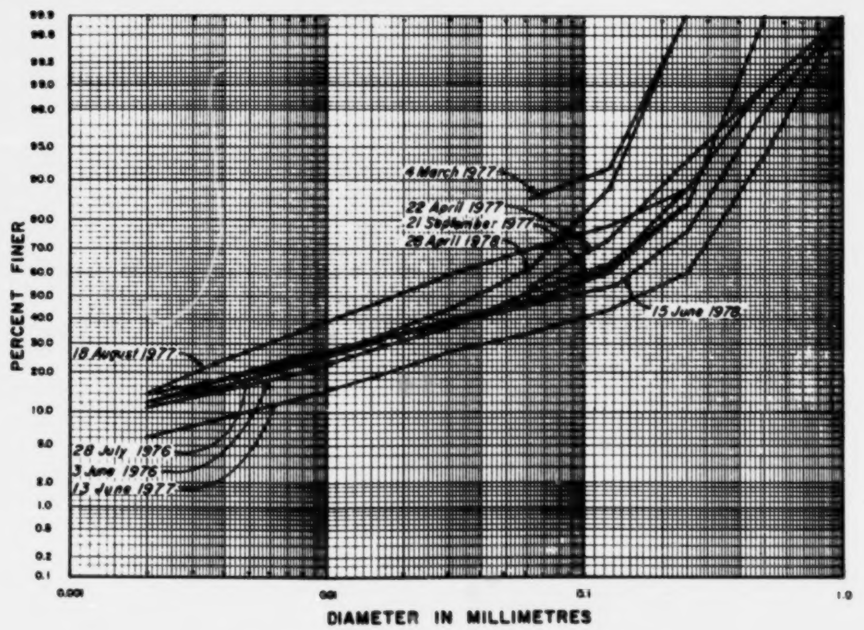
STIKINE RIVER ABOVE GRAND CANYON



CHUTINE RIVER BELOW WRIGGLE CREEK



STIKINE RIVER ABOVE BUTTERFLY CREEK



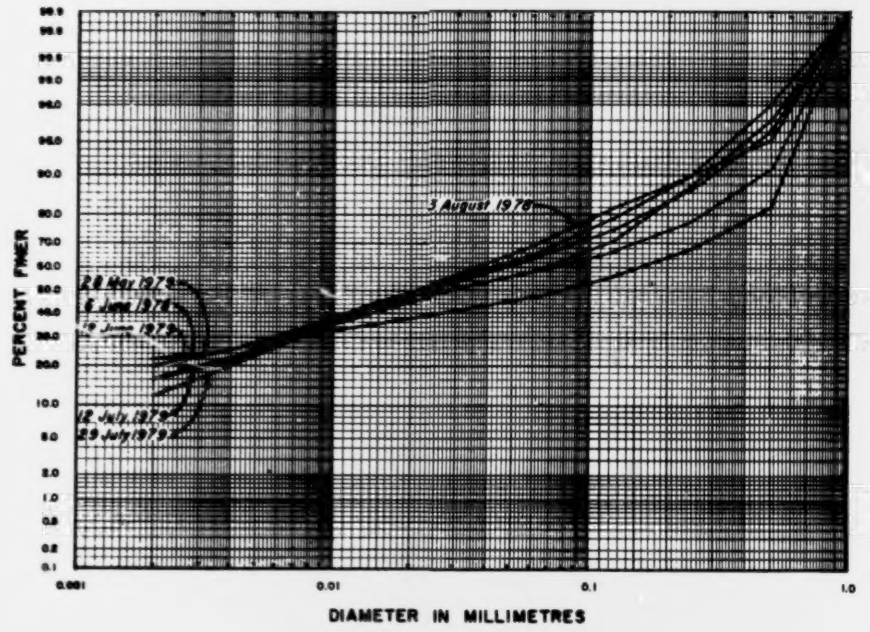
STIKINE RIVER NEAR WRANGELL, ALASKA

BRITISH COLUMBIA HYDRO AND POWER AUTHORITY

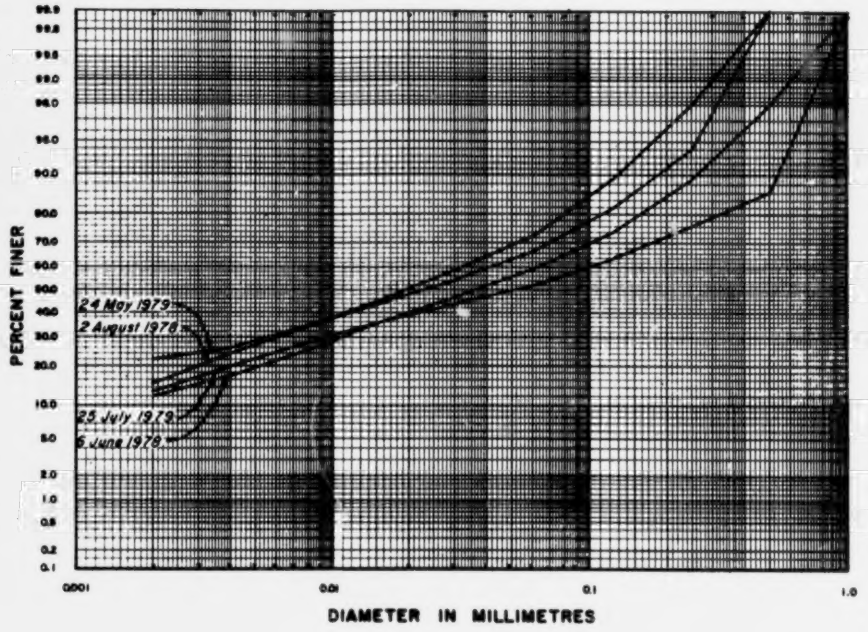
STIKINE - ISKUT FEASIBILITY STUDY
HYDROLOGY, RIVER REGIME & MORPHOLOGY
GRAIN SIZE DISTRIBUTION
SUSPENDED SEDIMENT SHEET 1 OF 2

DATE AUG 1980	PLATE 5-1	R
DWN KL / JMB	DWG No. 915-C14-D118	

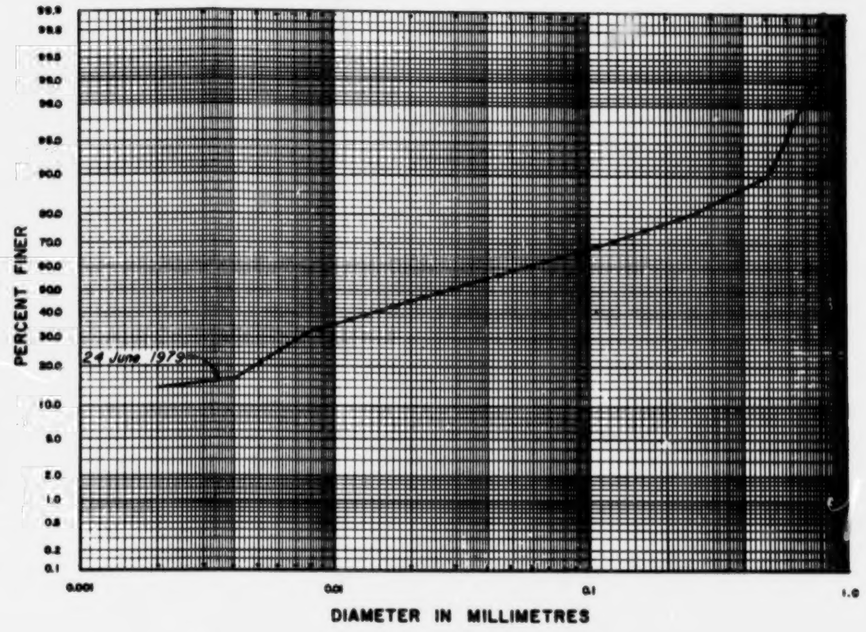
REPORT No. H-1110



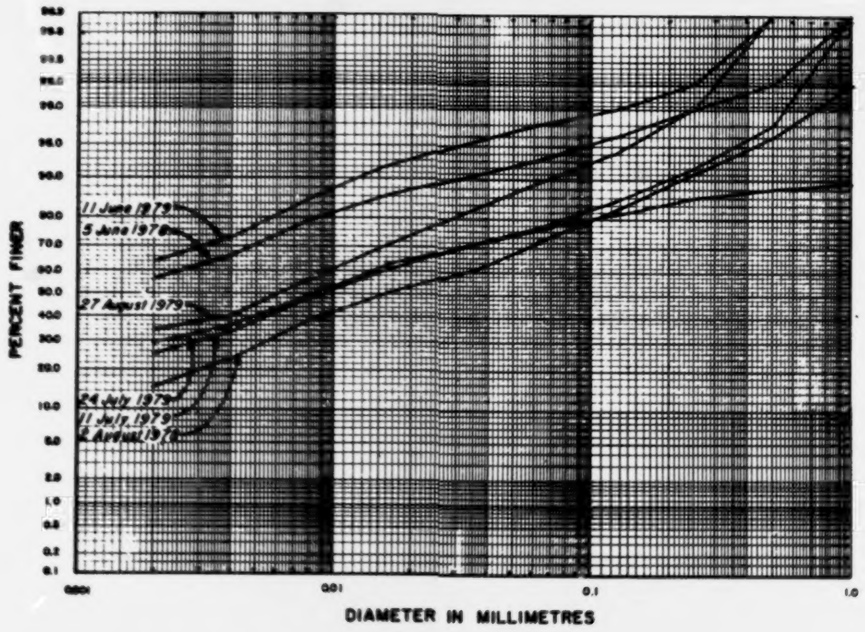
ISKUT RIVER BELOW JOHNSON RIVER



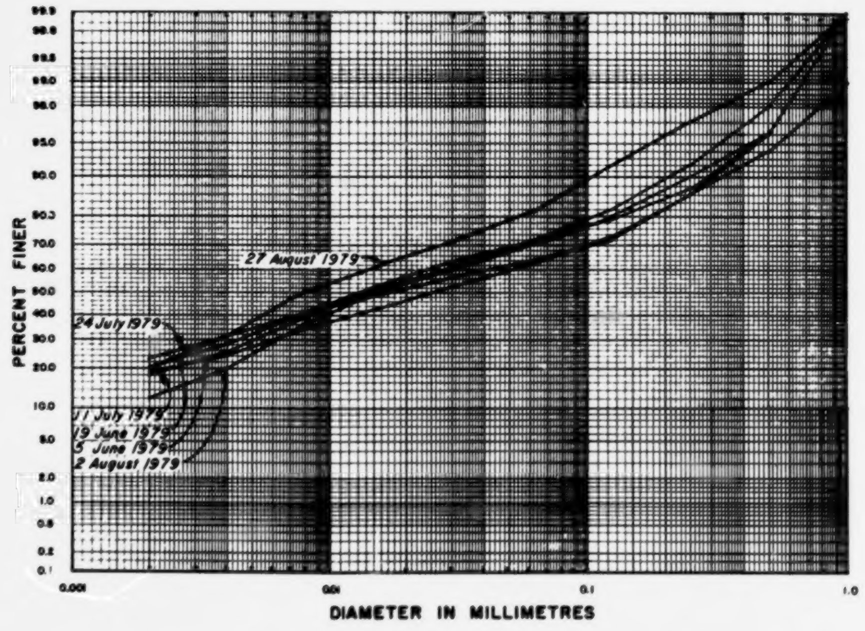
ISKUT RIVER ABOVE SNIPPAKER CREEK



CRAIG RIVER NEAR THE MOUTH



FORREST KERR CREEK ABOVE 460m CONTOUR



MORE CREEK NEAR THE MOUTH

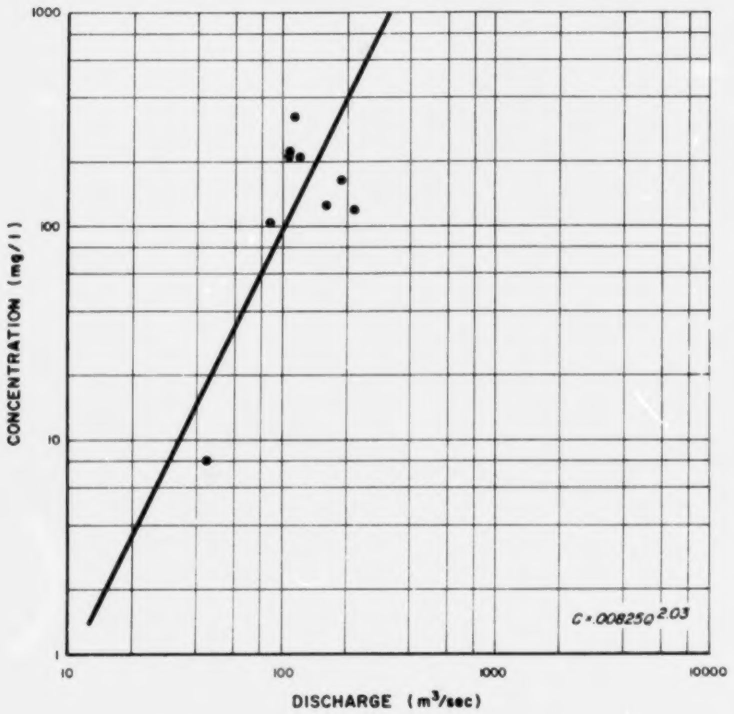
BRITISH COLUMBIA HYDRO AND POWER AUTHORITY

STIKINE - ISKUT FEASIBILITY STUDY

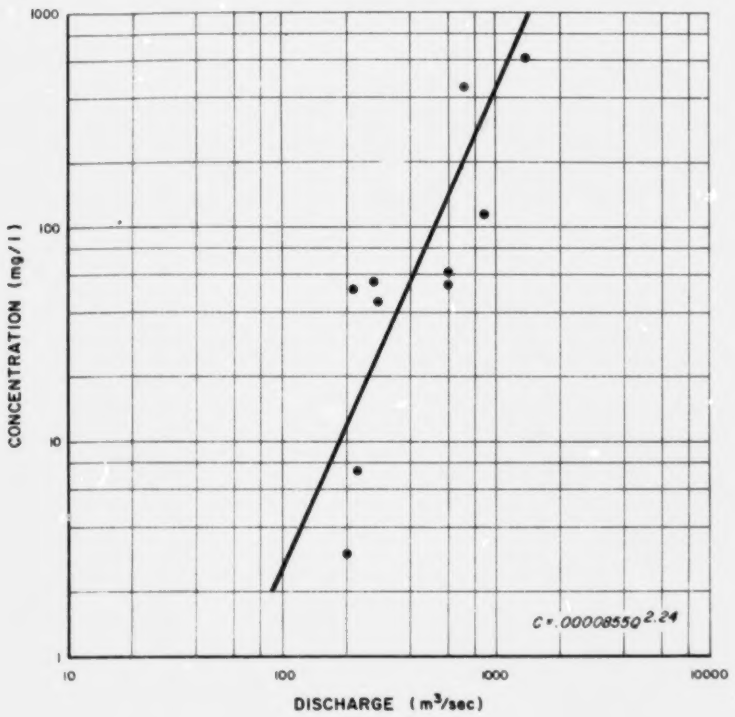
HYDROLOGY, RIVER REGIME & MORPHOLOGY
GRAIN SIZE DISTRIBUTION
SUSPENDED SEDIMENT SHEET 2 OF 2

DATE AUG 1980	PLATE 5-1	R
DWN KL / JMB	DWG No. 915 - C14 - D119	

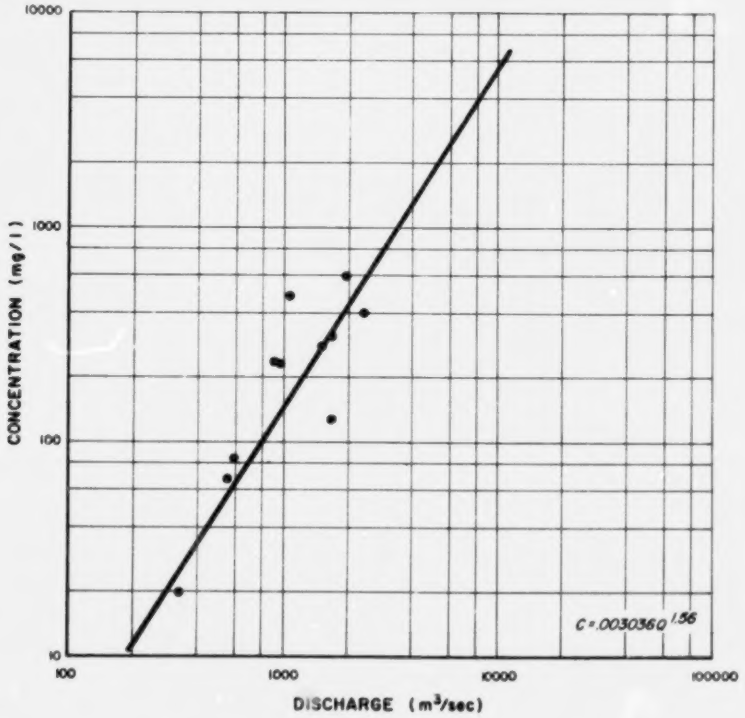
REPORT No. H-1110



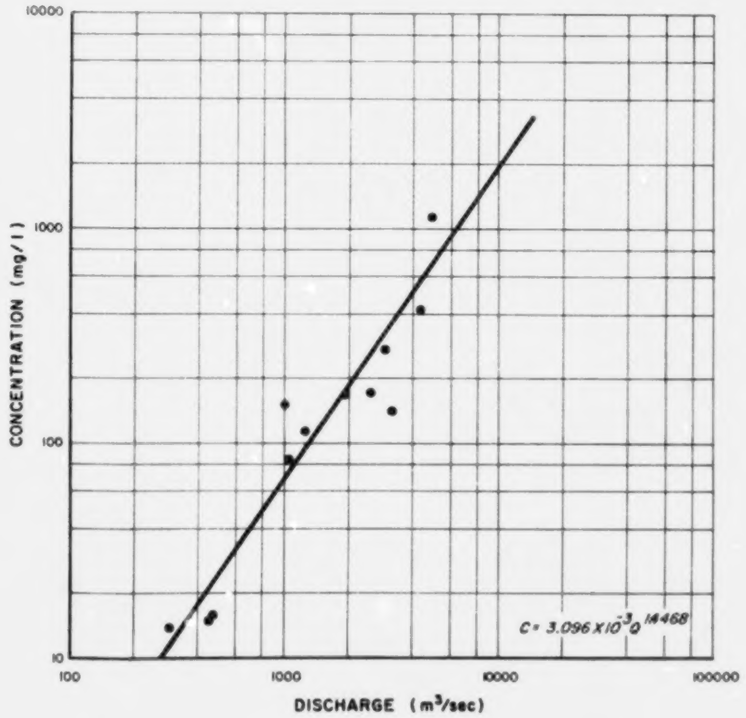
KLAPPAN RIVER NEAR TELEGRAPH CREEK



STIKINE RIVER ABOVE GRAND CANYON



STIKINE RIVER ABOVE BUTTERFLY CREEK



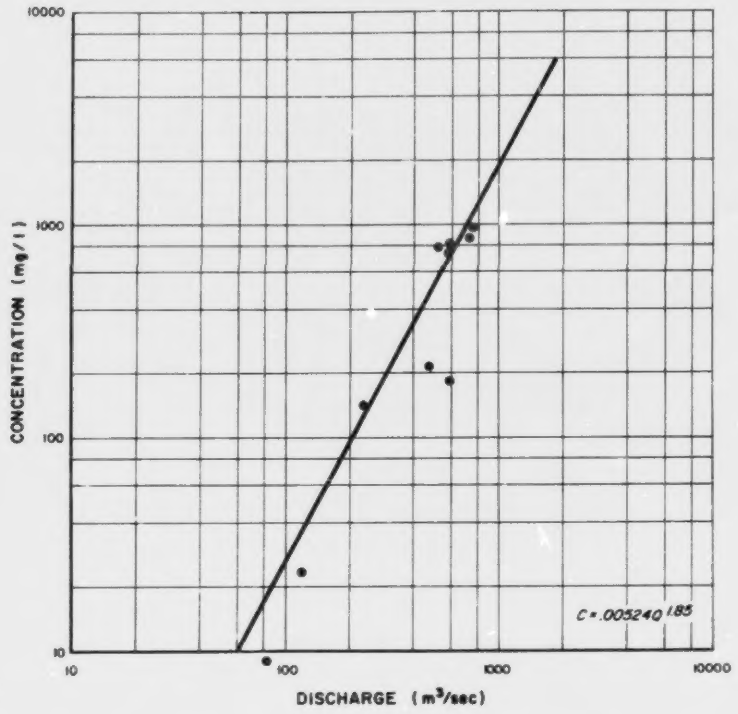
STIKINE RIVER NEAR WRANGELL, ALASKA

BRITISH COLUMBIA HYDRO AND POWER AUTHORITY

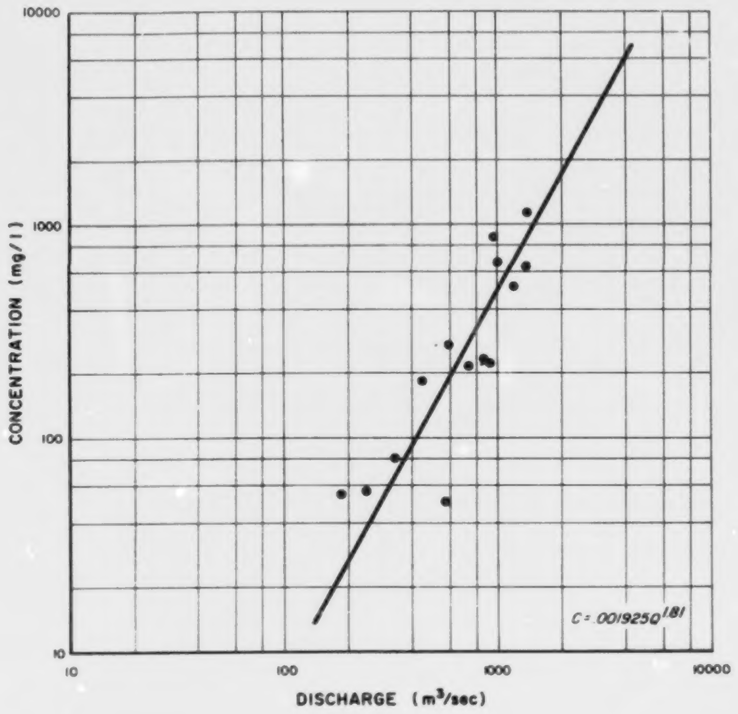
STIKINE - ISKUT FEASIBILITY STUDY
HYDROLOGY, RIVER REGIME & MORPHOLOGY
SUSPENDED SEDIMENT RATING CURVES
SHEET 1 OF 2

DATE AUG 1980	PLATE 5 - 2	R
DWN K.L.	DWG No. 915 - C14 - D120	

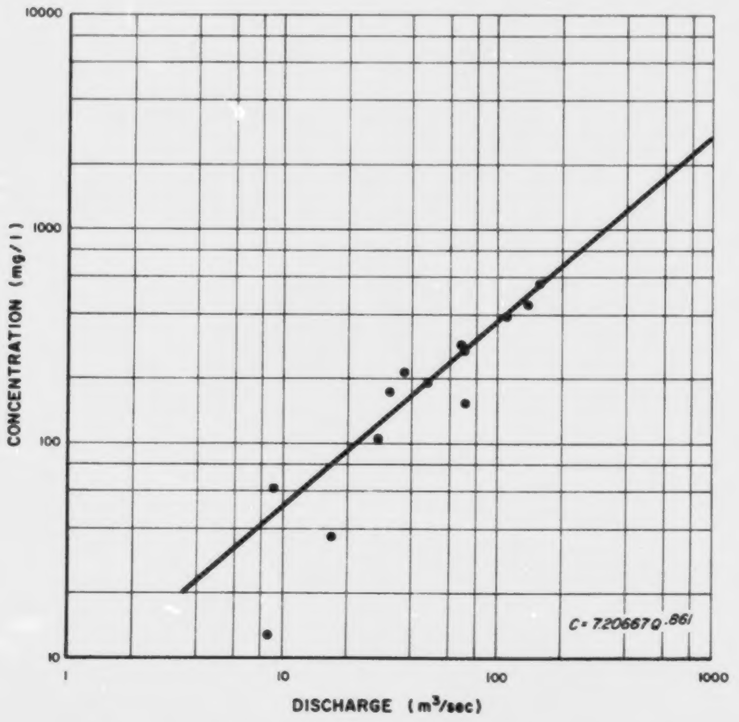
REPORT No H-1110



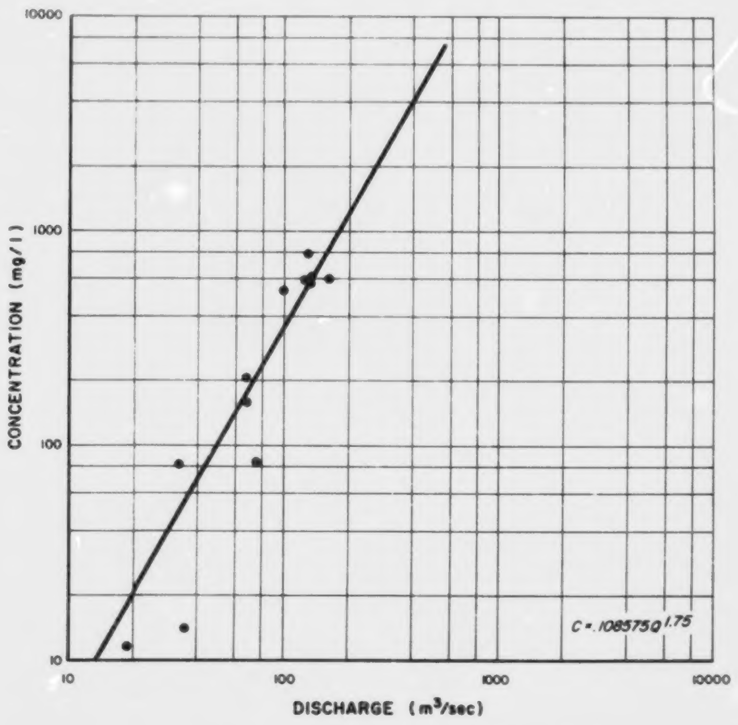
ISKUT RIVER ABOVE SNIPPAKER CREEK



ISKUT RIVER BELOW JOHNSON RIVER



FORREST KERR CREEK ABOVE 460 METRE CONTOUR



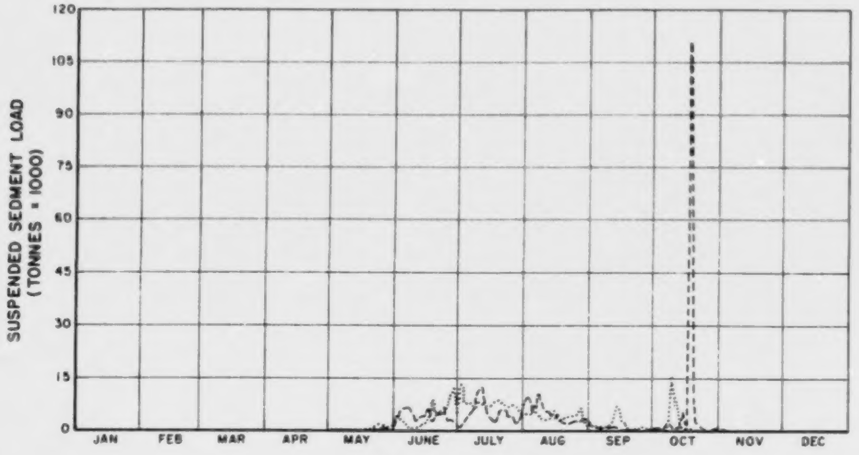
MORE CREEK NEAR THE MOUTH

BRITISH COLUMBIA HYDRO AND POWER AUTHORITY

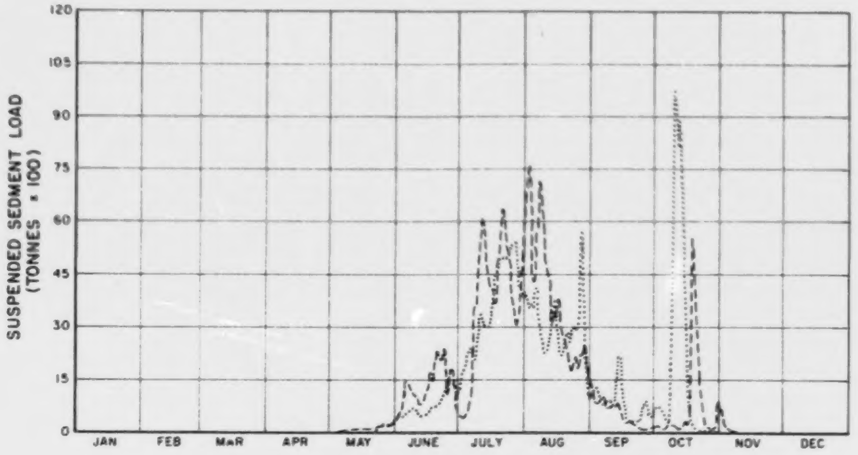
STIKINE - ISKUT FEASIBILITY STUDY
HYDROLOGY, RIVER REGIME & MORPHOLOGY
SUSPENDED SEDIMENT RATING CURVES
SHEET 2 OF 2

DATE AUG 1980	PLATE 5 - 2	R
DWN K.L.	DWG No. 915 - C14 - D121	

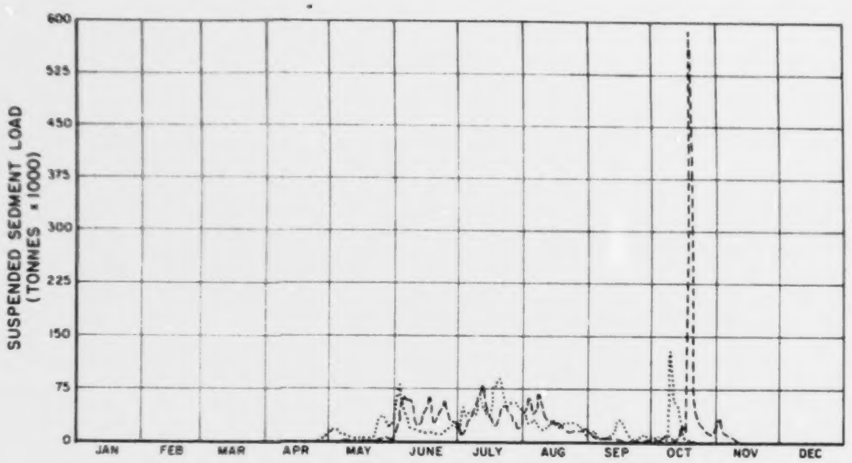
REPORT No. H-1110



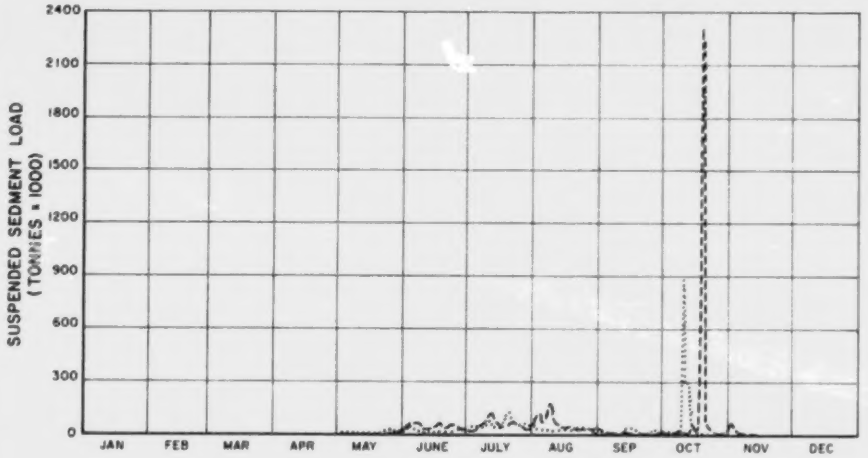
MORE CREEK NEAR THE MOUTH



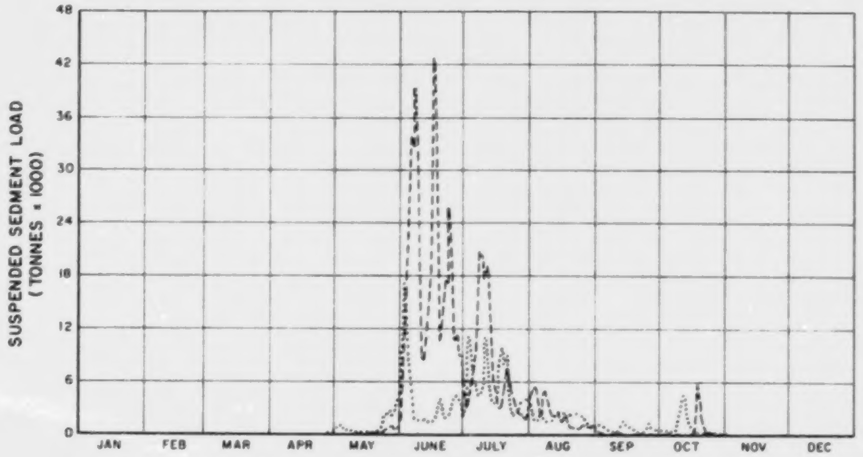
FORREST KERR CREEK ABOVE 460 M CONTOUR



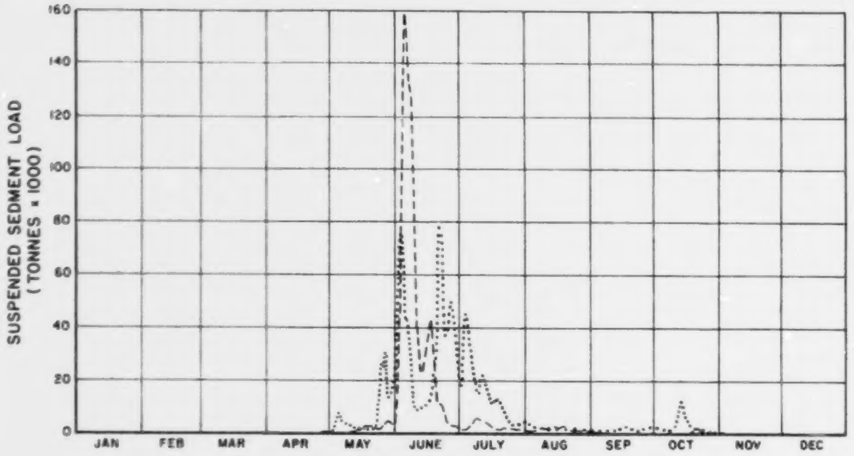
ISKUT RIVER ABOVE SNIPPAKER CREEK



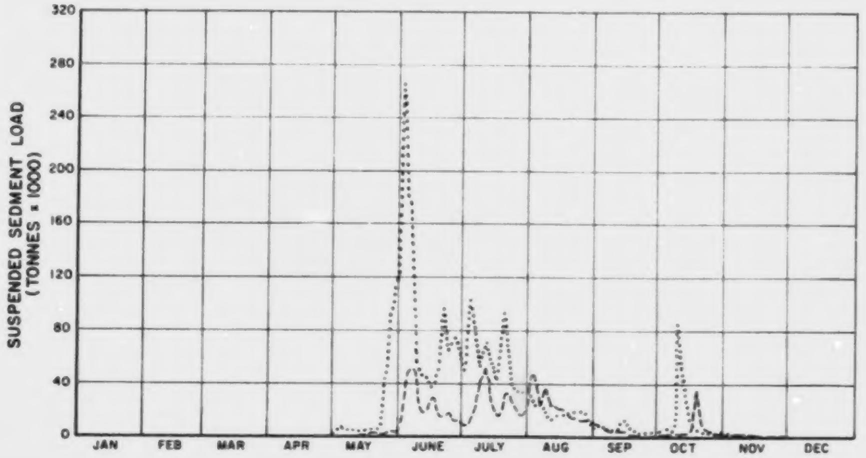
ISKUT RIVER BELOW JOHNSON RIVER



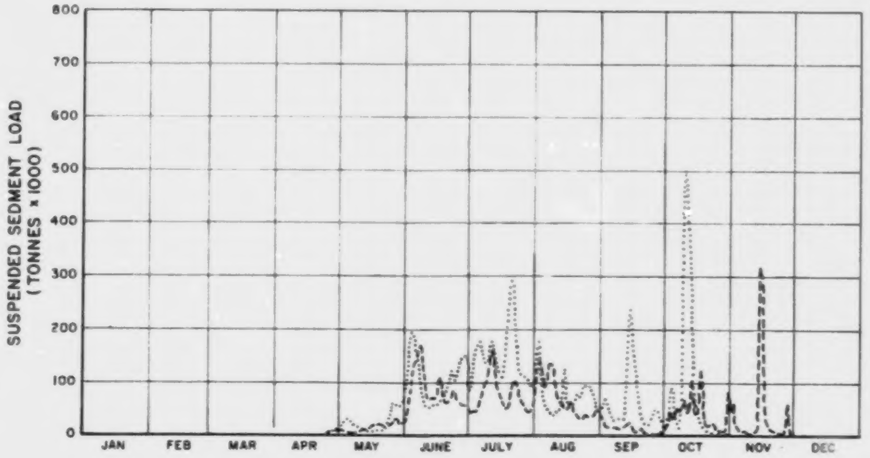
KLAPPAN RIVER NEAR TELEGRAPH CREEK



STIKINE RIVER ABOVE GRAND CANYON



STIKINE RIVER ABOVE BUTTERFLY CREEK



STIKINE RIVER NEAR WRANGELL ALASKA

LEGEND:
- - - - 1978
·········· 1979

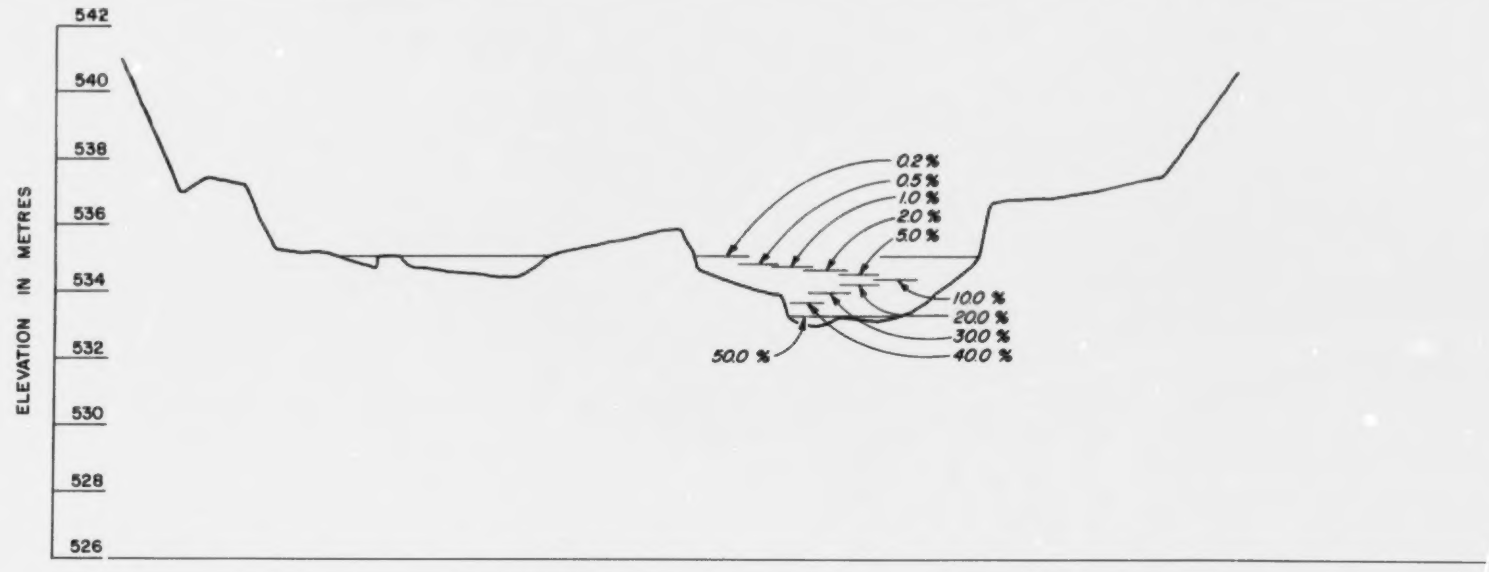
BRITISH COLUMBIA HYDRO AND POWER AUTHORITY

STIKINE - ISKUT FEASIBILITY STUDY

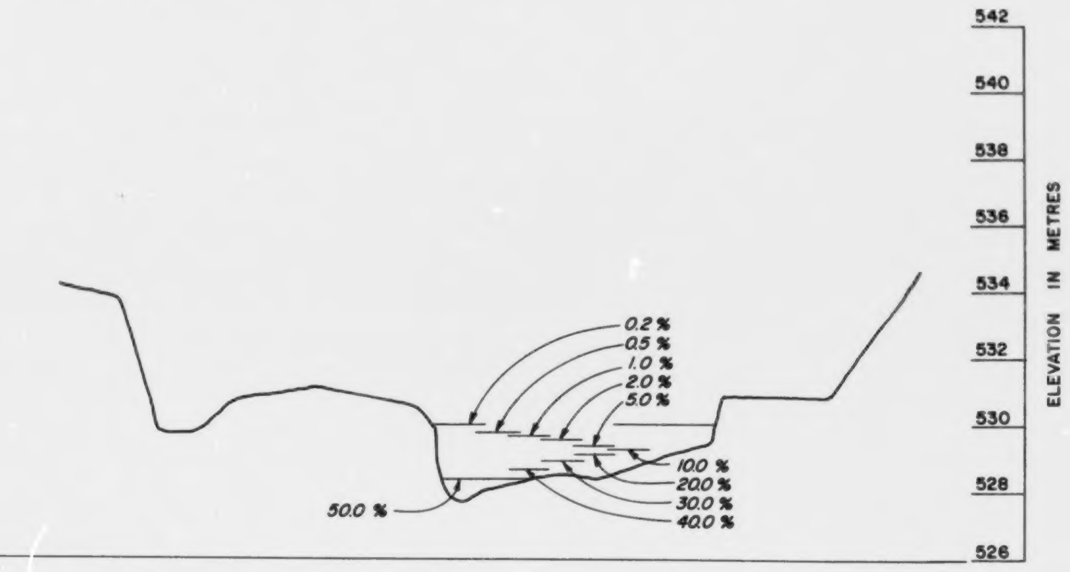
HYDROLOGY, RIVER REGIME & MORPHOLOGY
SUSPENDED SEDIMENT LOAD

DATE AUG 1980	PLATE 5-3	R
DWN A.H.	DWG No. 915 - C14 - D122	

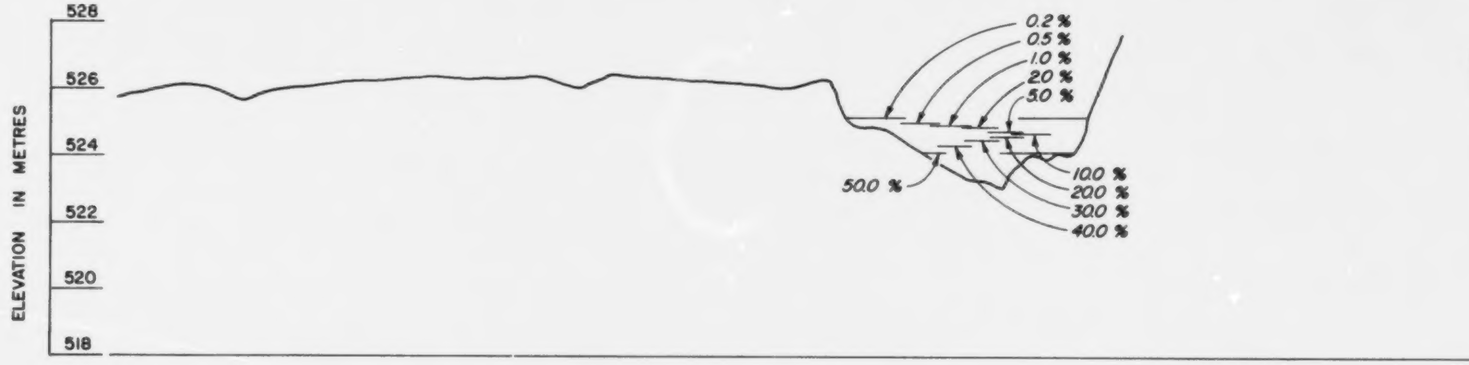
REPORT No. H-1110


542
540
538
536
534
532
530
528
526
ELEVATION IN METRES
0.2 %
0.5 %
1.0 %
2.0 %
5.0 %
10.0 %
20.0 %
30.0 %
40.0 %
50.0 %

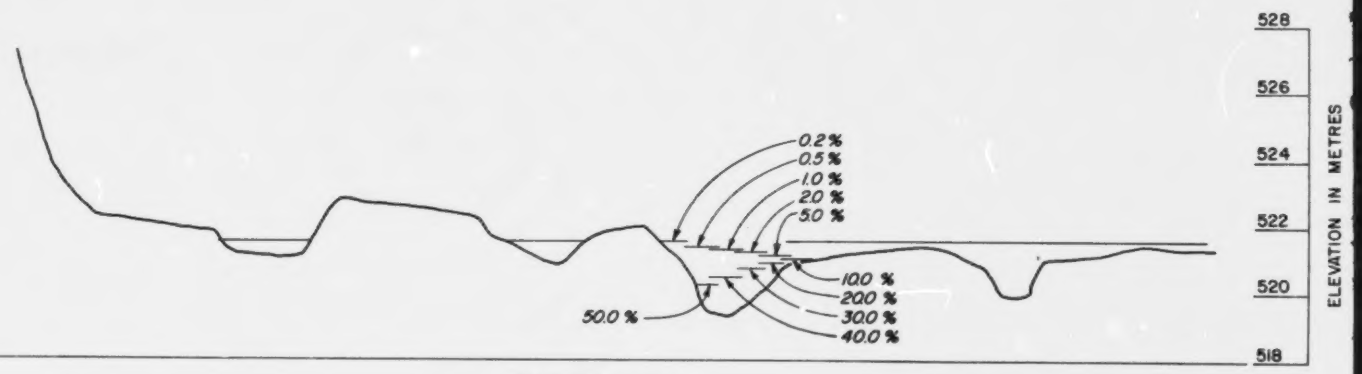
SECTION M-1


542
540
538
536
534
532
530
528
526
ELEVATION IN METRES
0.2 %
0.5 %
1.0 %
2.0 %
5.0 %
10.0 %
20.0 %
30.0 %
40.0 %
50.0 %

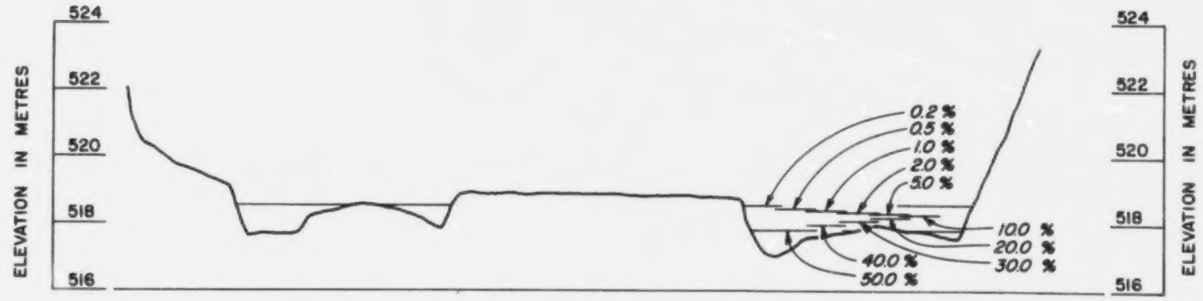
SECTION M-2


528
526
524
522
520
518
ELEVATION IN METRES
0.2 %
0.5 %
1.0 %
2.0 %
5.0 %
10.0 %
20.0 %
30.0 %
40.0 %
50.0 %

SECTION M-3


528
526
524
522
520
518
ELEVATION IN METRES
0.2 %
0.5 %
1.0 %
2.0 %
5.0 %
10.0 %
20.0 %
30.0 %
40.0 %
50.0 %

SECTION M-4


524
522
520
518
516
ELEVATION IN METRES
0.2 %
0.5 %
1.0 %
2.0 %
5.0 %
10.0 %
20.0 %
30.0 %
40.0 %
50.0 %

SECTION M-5

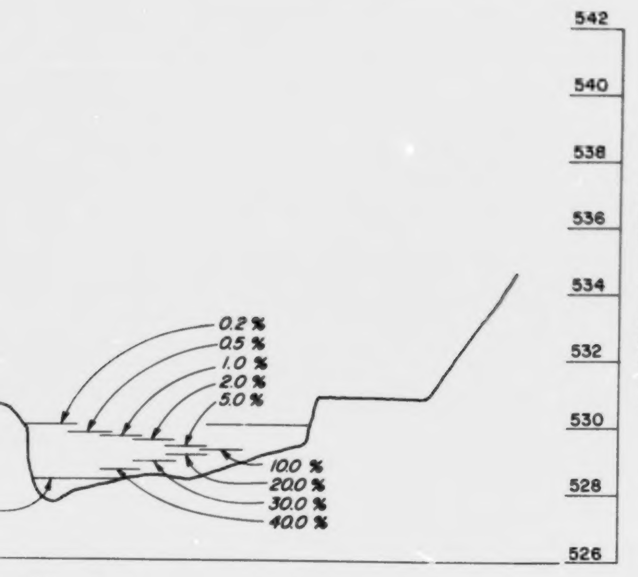
NOTE:
WATER L
INDICAT
DERIVED

Horizontal

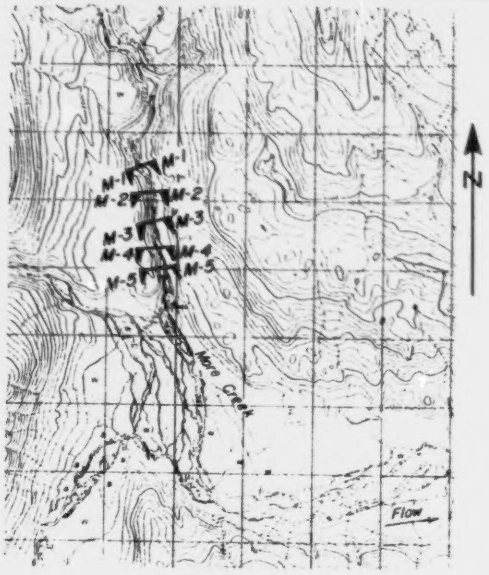
STIKI
HYD
MOR
CRO

DATE

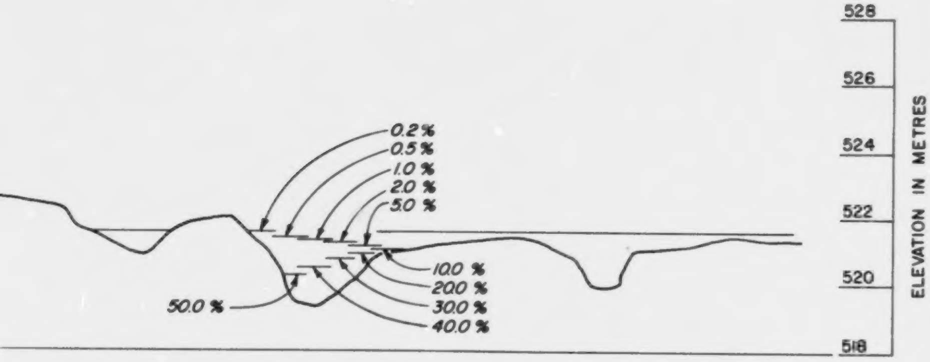
DWN S


542
540
538
536
534
532
530
528
526
ELEVATION IN METRES
0.2 %
0.5 %
1.0 %
2.0 %
5.0 %
10.0 %
20.0 %
30.0 %
40.0 %

TION M-2


M-1
M-1
M-2
M-2
M-3
M-3
M-4
M-4
M-5
M-5
More Creek
Flow
N

KEY PLAN
Scale = 1:50000
(For area location see Plate 1 of 2)


528
526
524
522
520
518
ELEVATION IN METRES
0.2 %
0.5 %
1.0 %
2.0 %
5.0 %
10.0 %
20.0 %
30.0 %
40.0 %
50.0 %

SECTION M-4

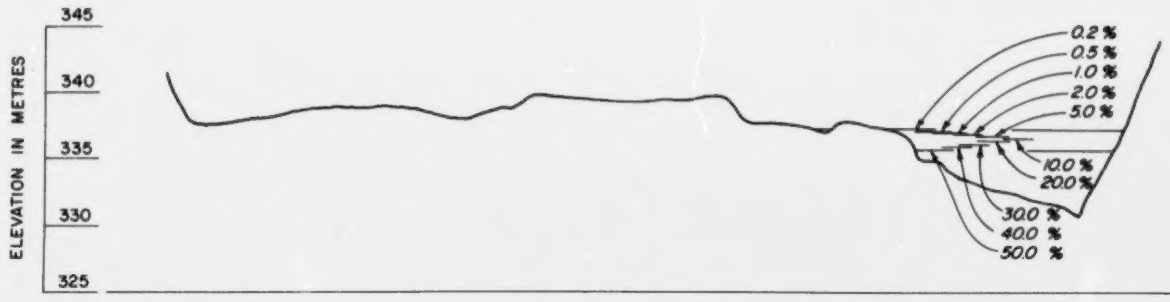
NOTE:
WATER LEVELS SHOWN ARE FOR FLOWS OF INDICATED EXCEEDANCE PROBABILITIES DERIVED FROM FLOW DURATION ANALYSIS.

Horizontal Scale: 10 0 10 20 30 40 Metres

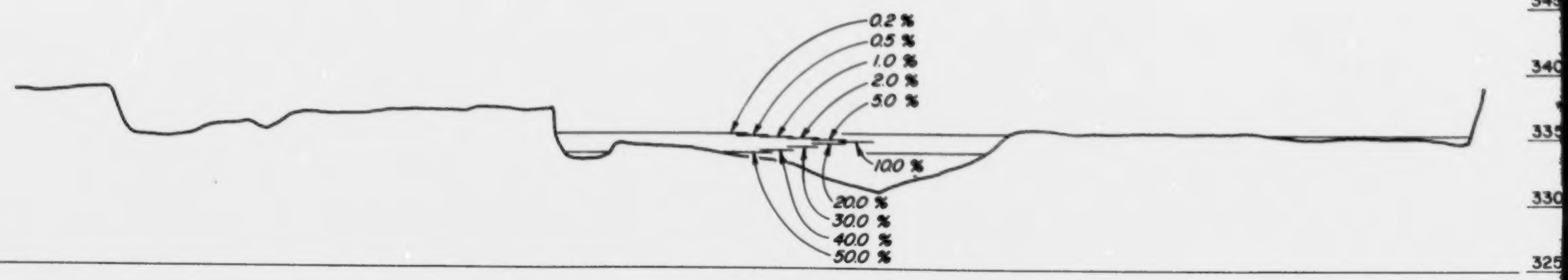
BRITISH COLUMBIA HYDRO AND POWER AUTHORITY

STIKINE - ISKUT FEASIBILITY STUDY
HYDROLOGY, RIVER REGME & MORPHOLOGY
MORE CREEK TEST REACH
CROSS - SECTIONS

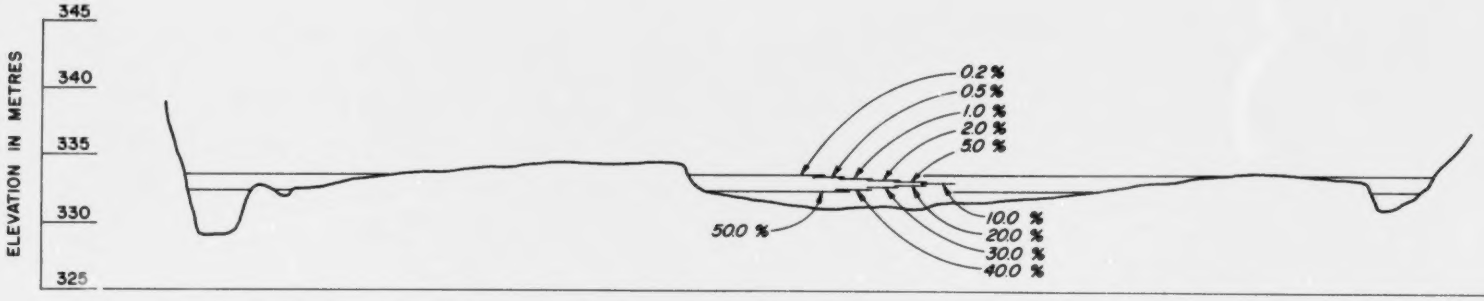
DATE AUG 1980	PLATE 5 - 4	R
DWN SMD	DWG No. 915 - C14 - U123	


345
340
335
330
325
ELEVATION IN METRES
0.2 %
0.5 %
1.0 %
2.0 %
5.0 %
10.0 %
20.0 %
30.0 %
40.0 %
50.0 %

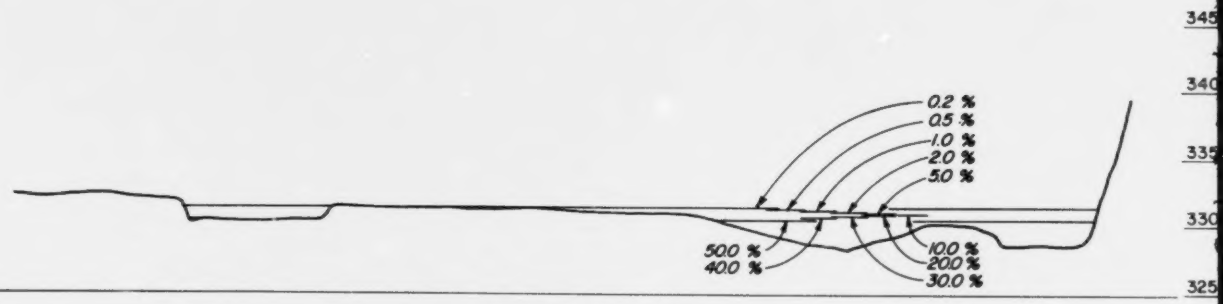
SECTION 1-1


0.2 %
0.5 %
1.0 %
2.0 %
5.0 %
10.0 %
20.0 %
30.0 %
40.0 %
50.0 %
345
340
335
330
325

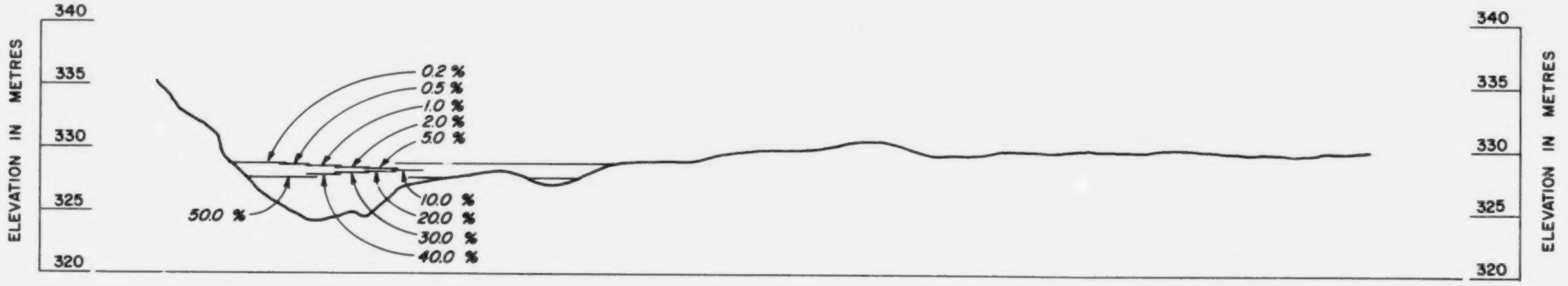
SECTION 1-2


345
340
335
330
325
ELEVATION IN METRES
0.2 %
0.5 %
1.0 %
2.0 %
5.0 %
50.0 %
10.0 %
20.0 %
30.0 %
40.0 %

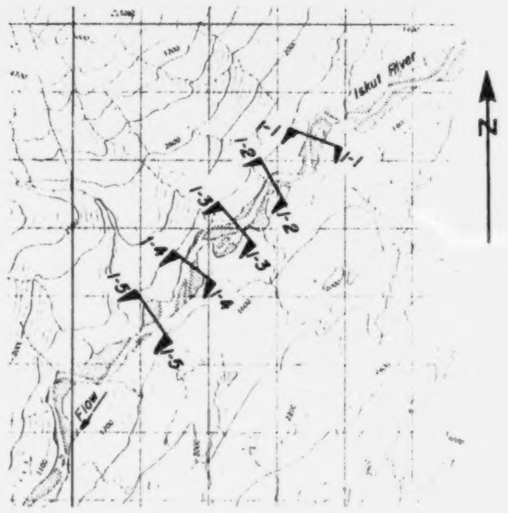
SECTION 1-3


0.2 %
0.5 %
1.0 %
2.0 %
5.0 %
50.0 %
40.0 %
10.0 %
20.0 %
30.0 %
345
340
335
330
325

SECTION 1-4


340
335
330
325
320
ELEVATION IN METRES
0.2 %
0.5 %
1.0 %
2.0 %
5.0 %
50.0 %
10.0 %
20.0 %
30.0 %
40.0 %
340
335
330
325
320
ELEVATION IN METRES

SECTION 1-5


Iskut River
N
1-1
1-2
1-3
1-4
1-5
Flow

KEY PLAN
Scale = 1:50000
(For area location see Plate 1 of 2)

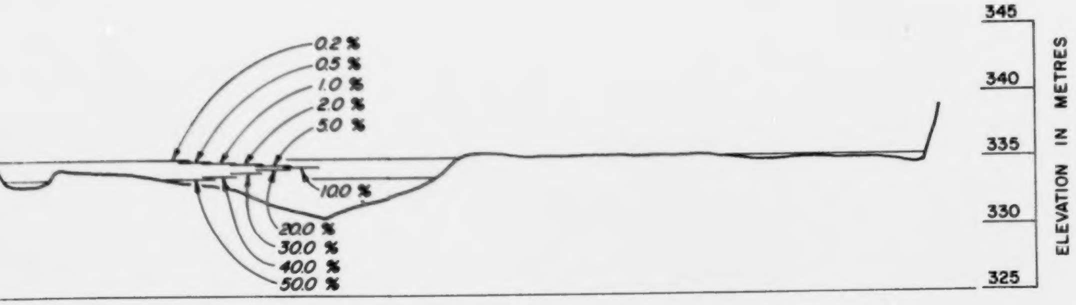
NOTE:
WATER LEVELS SHOWN ARE
OF INDICATED EXCEEDANCE
DERIVED FROM FLOW DURAT

Horizontal Scale: 2

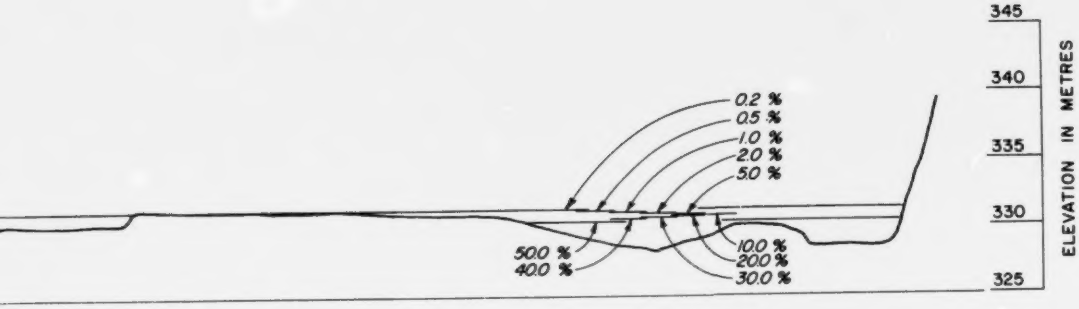
BRITISH CO
STIKINE - ISKU
HYDROLOGY,
UPPER ISKU
CROSS - SE

DATE AUG 1980

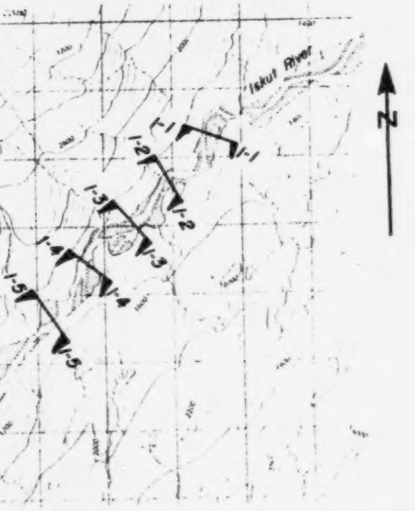
DWN SMD



SECTION 1-2



SECTION 1-4



KEY PLAN

Scale = 1:50000

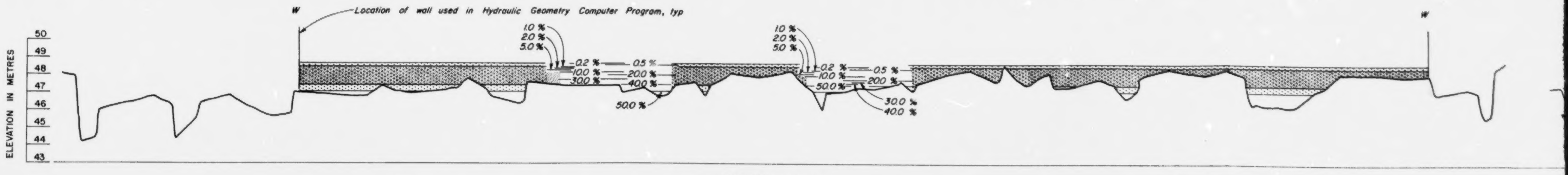
(For area location see Plate 1 of 2)

NOTE:

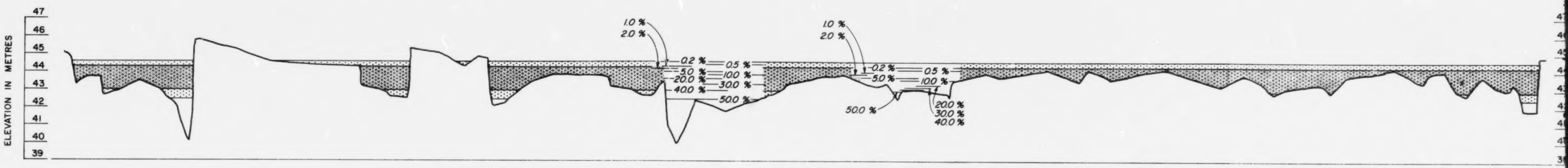
WATER LEVELS SHOWN ARE FOR FLOWS OF INDICATED EXCEEDANCE PROBABILITIES DERIVED FROM FLOW DURATION ANALYSIS.

Horizontal Scale: 20 0 20 40 60 80 *Metres*

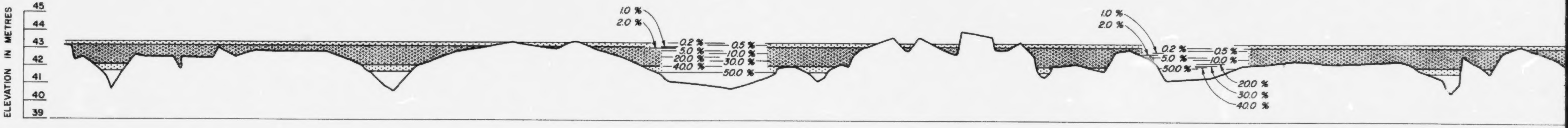
BRITISH COLUMBIA HYDRO AND POWER AUTHORITY	
STIKINE - ISKUT FEASIBILITY STUDY **HYDROLOGY, RIVER REGIME & MORPHOLOGY** **UPPER ISKUT RIVER TEST REACH** **CROSS - SECTIONS**	
DATE AUG 1980	**PLATE 5-5** R
DWN SMD	DWG No. 915 - C14 - U124



SECTION L1-1



SECTION L1-2



SECTION L1-3

LEGEND

░ Pre-project

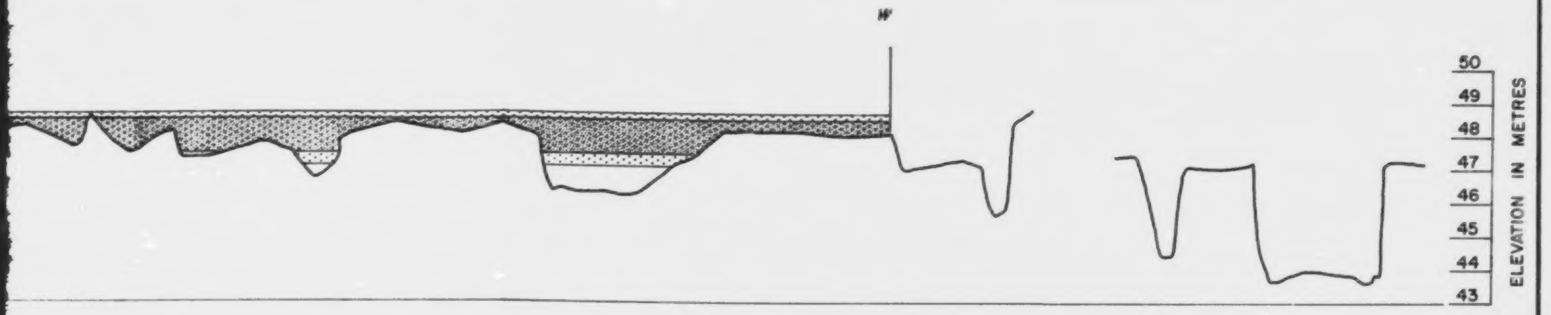
▓ Post-project

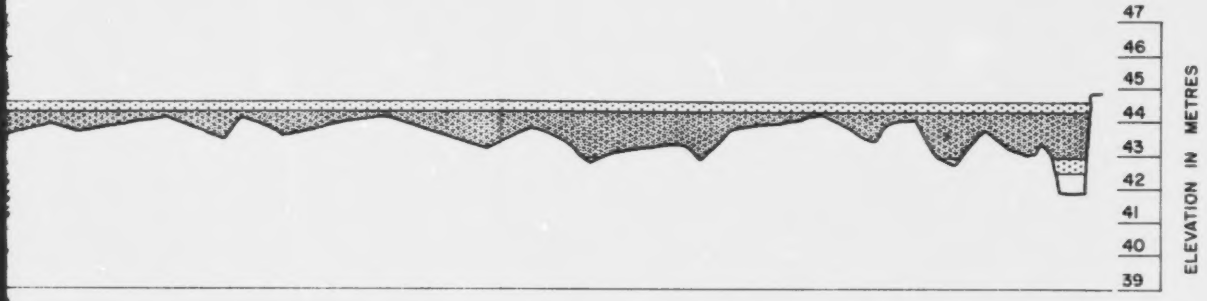
Horizontal Scale: 50

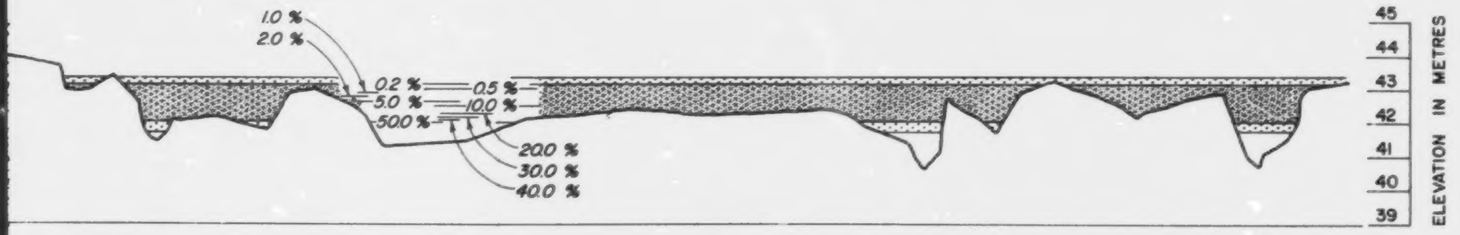
NOTE:
WATER LEVELS SHOWN ARE FOR FLOWS
OF INDICATED EXCEEDANCE PROBABILITIES
DERIVED FROM FLOW DURATION ANALYSIS.

BRITISH COL
STIKINE - ISKUT
HYDROLOGY,
LOWER ISKUT
CROSS - SEC

DATE AUG 1980
DWN SMD







LEGEND

░ *Pre-project*

▓ *Post-project*

NOTE:

WATER LEVELS SHOWN ARE FOR FLOWS
OF INDICATED EXCEEDANCE PROBABILITIES
DERIVED FROM FLOW DURATION ANALYSIS.

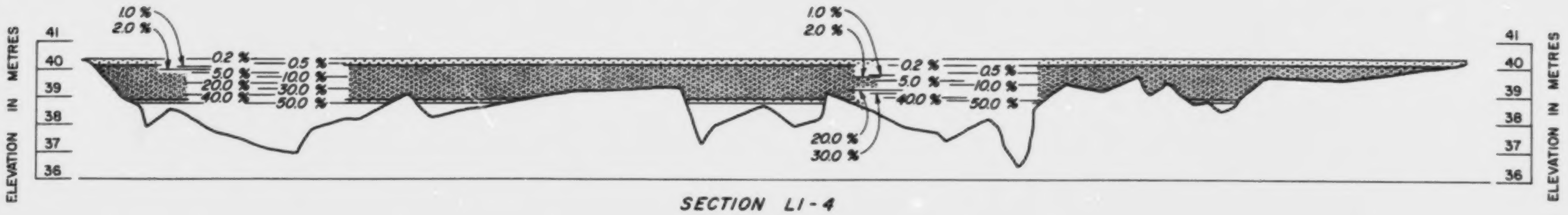
Horizontal Scale: 50 0 50 100 150 *Metres*

BRITISH COLUMBIA HYDRO AND POWER AUTHORITY

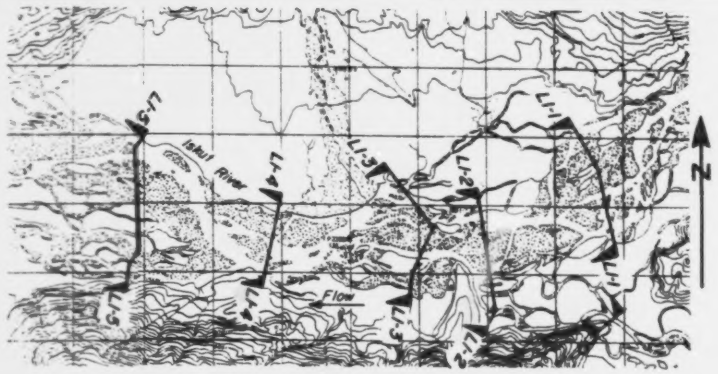
STIKINE - ISKUT FEASIBILITY STUDY

HYDROLOGY, RIVER REGIME & MORPHOLOGY
LOWER ISKUT RIVER TEST REACH
CROSS - SECTIONS - SHEET 1 OF 2

DATE AUG 1980	PLATE 5 - 6	R
DWN SMD	DWG No. 915 - C14 - U202	


1.0 %
2.0 %
0.2 %
0.5 %
5.0 %
10.0 %
20.0 %
30.0 %
40.0 %
50.0 %
1.0 %
2.0 %
0.2 %
0.5 %
5.0 %
10.0 %
40.0 %
50.0 %
20.0 %
30.0 %
41
40
39
38
37
36
ELEVATION IN METRES

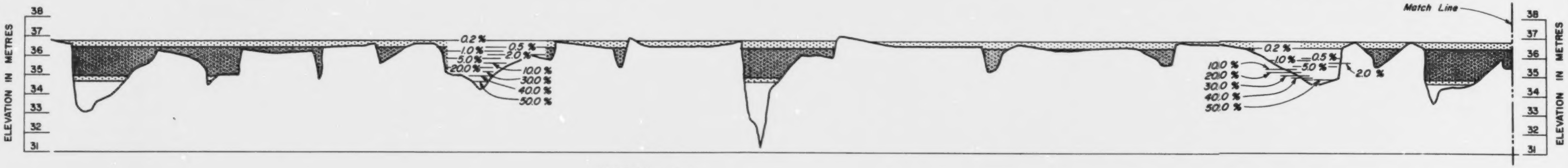
SECTION LI-4


Iskut River
Flow
LI-1
LI-2
LI-3
LI-4
LI-5
N

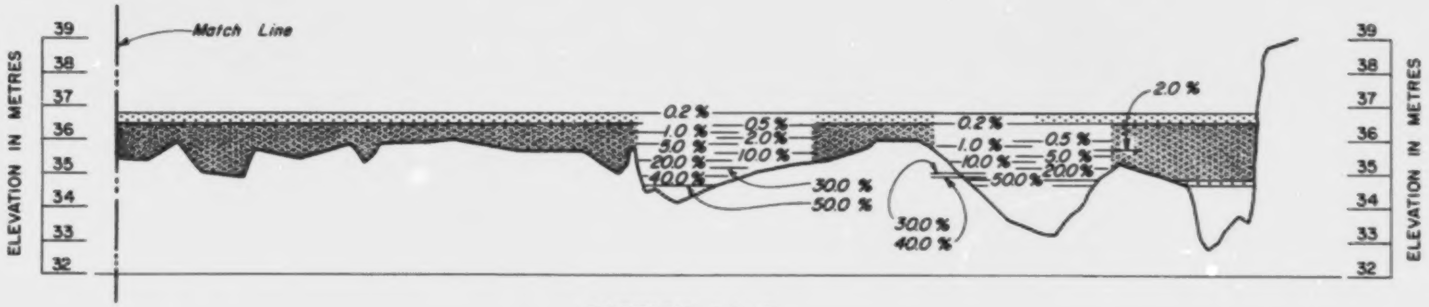
KEY PLAN

Scale : 1:50 000

(For area location see Plate 1 of 2)


Match Line
0.2 %
1.0 %
5.0 %
20.0 %
0.5 %
2.0 %
10.0 %
30.0 %
40.0 %
50.0 %
0.2 %
1.0 %
0.5 %
5.0 %
2.0 %
10.0 %
20.0 %
30.0 %
40.0 %
50.0 %
38
37
36
35
34
33
32
31
ELEVATION IN METRES

SECTION LI-5


Match Line
0.2 %
1.0 %
5.0 %
20.0 %
40.0 %
0.5 %
2.0 %
10.0 %
30.0 %
50.0 %
0.2 %
1.0 %
10.0 %
0.5 %
5.0 %
20.0 %
50.0 %
30.0 %
40.0 %
2.0 %
39
38
37
36
35
34
33
32
ELEVATION IN METRES

SECTION LI-5

LEGEND

- ░ Pre-project
- ▓ Post-project

NOTE:

WATER LEVELS SHOWN ARE FOR FLOWS OF INDICATED EXCEEDANCE PROBABILITIES DERIVED FROM FLOW DURATION ANALYSIS.

Horizontal Scale: 50 0 50 100 150 Metres

BRITISH COLUMBIA HYDRO AND POWER AUTHORITY

STIKINE - ISKUT FEASIBILITY STUDY

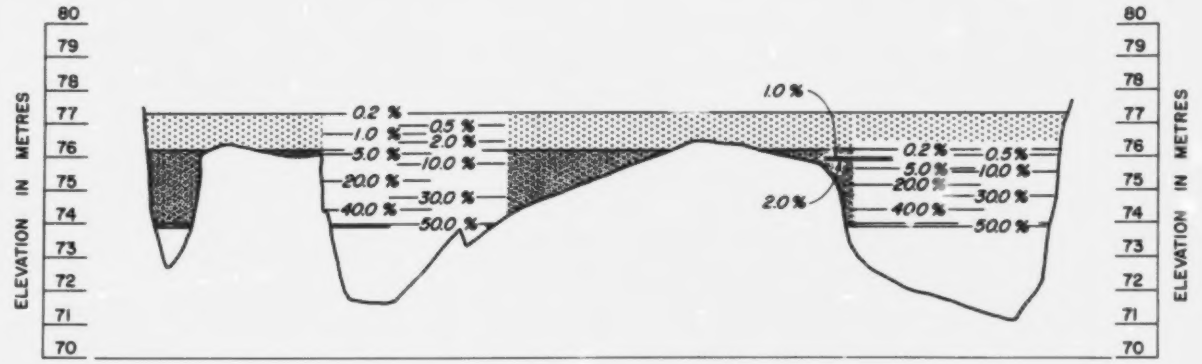
HYDROLOGY, RIVER REGIME & MORPHOLOGY

LOWER ISKUT RIVER TEST REACH

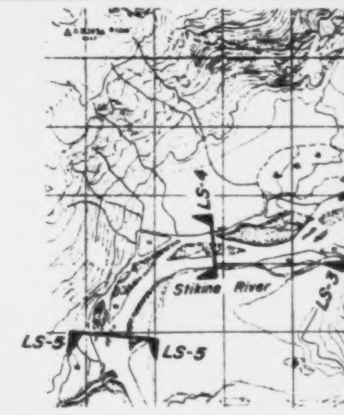
CROSS - SECTIONS - SHEET 2 OF 2

DATE AUG 1980	PLATE 5-6	R
DWN SMD	DWG No. 915 - C14 - D203	

REPORT No. H-1110



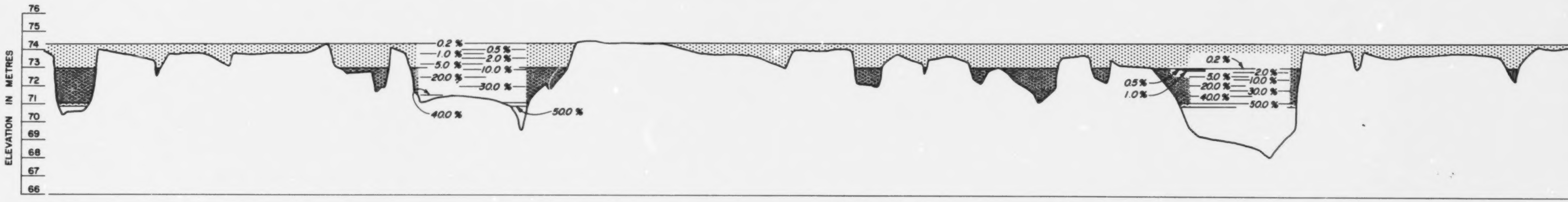
SECTION LS - 1


LS-4
Stikine River
LS-3
LS-5
LS-5

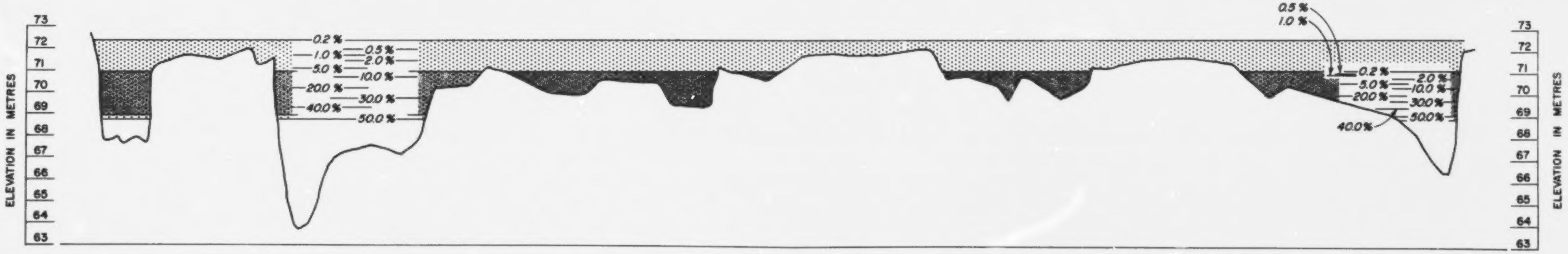
KE

Sca

(For area lo



SECTION LS - 2



SECTION LS - 3

LEG

▨

▩

NOTE:

WATER
OF IND
DERIVE

Horizontal Scale:

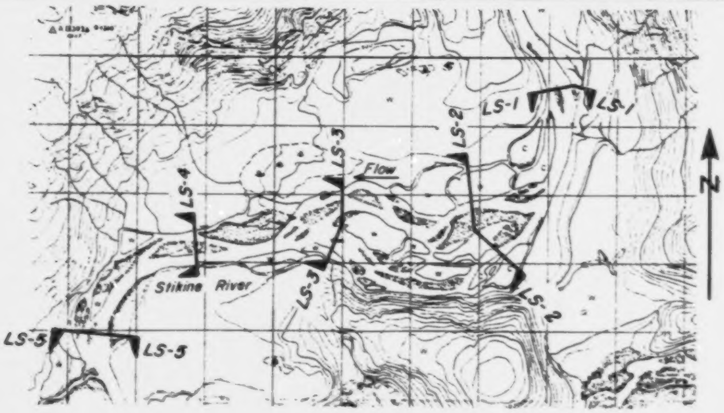
BRITIS

STIKINE - IS

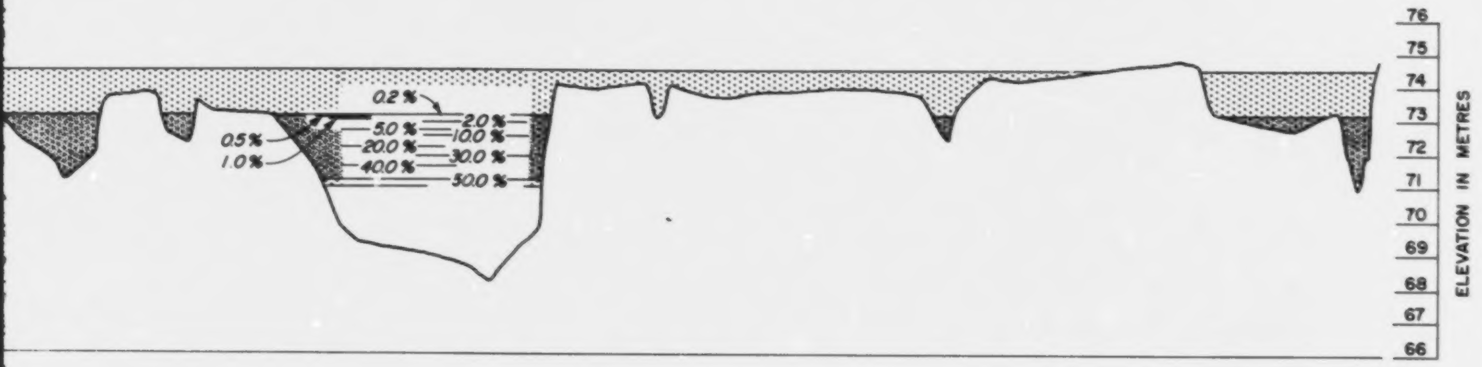
HYDROLOG
LOWER ST
CROSS - S

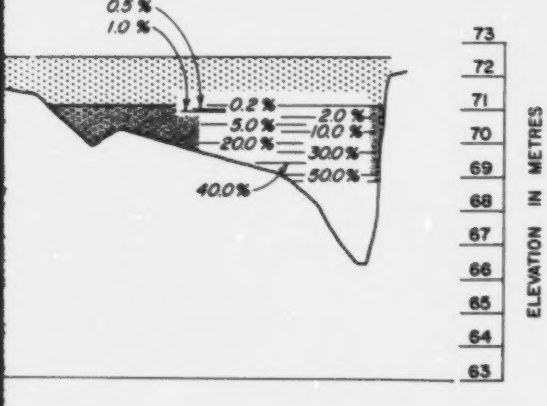
DATE AUG 19

DWN SMD


LS-1
LS-1
LS-2
LS-2
LS-3
LS-3
LS-4
LS-5
LS-5
Flow
Stikine River
N

KEY PLAN
Scale: 1:50000
(For area location see Plate 1 of 2)


0.2 %
2.0 %
0.5 %
1.0 %
5.0 %
10.0 %
20.0 %
30.0 %
40.0 %
50.0 %
76
75
74
73
72
71
70
69
68
67
66
ELEVATION IN METRES


0.5 %
1.0 %
0.2 %
2.0 %
5.0 %
10.0 %
20.0 %
30.0 %
50.0 %
40.0 %
73
72
71
70
69
68
67
66
65
64
63
ELEVATION IN METRES

LEGEND

░ *Pre-project*

▓ *Post-project*

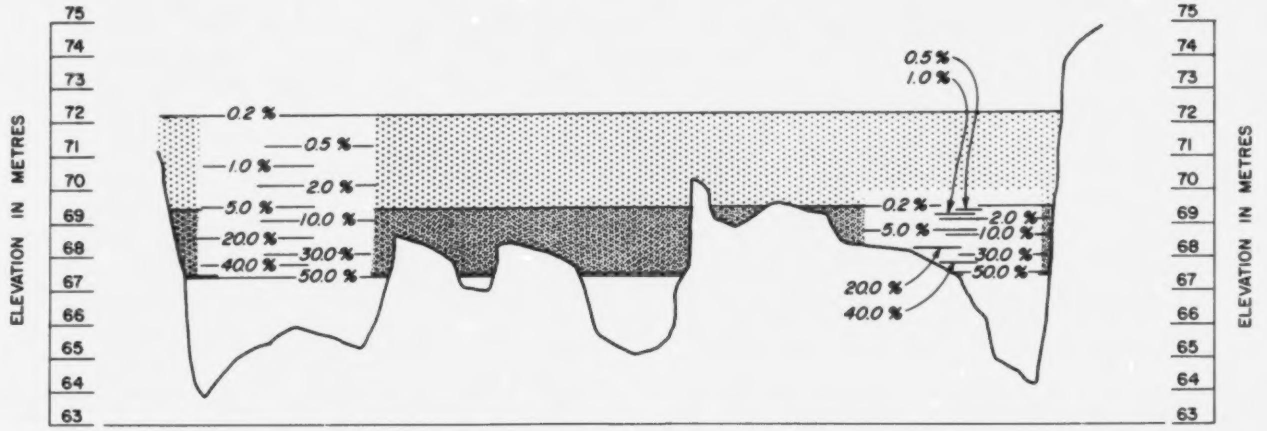
NOTE:
WATER LEVELS SHOWN ARE FOR FLOWS OF INDICATED EXCEEDANCE PROBABILITIES DERIVED FROM FLOW DURATION ANALYSIS.

Horizontal Scale: 50 0 50 100 150 Metres

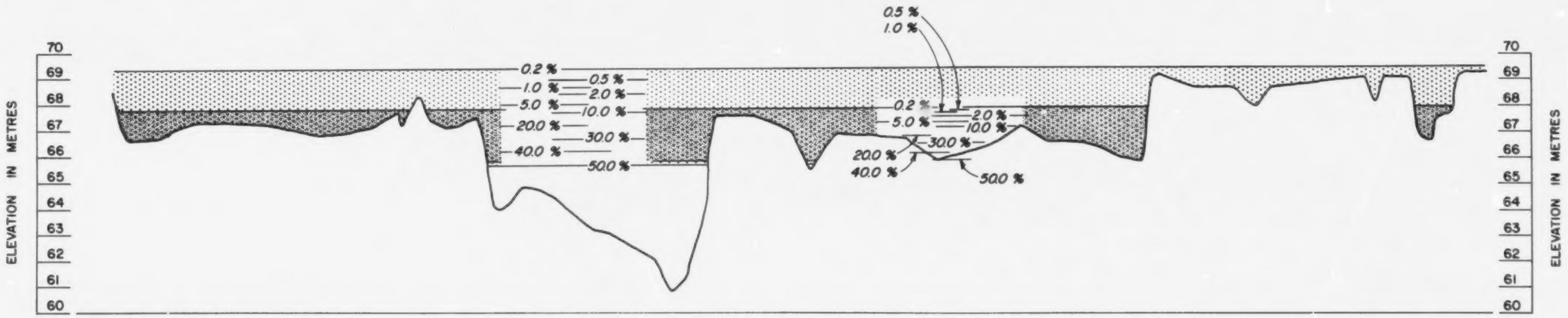
BRITISH COLUMBIA HYDRO AND POWER AUTHORITY

STIKINE - ISKUT FEASIBILITY STUDY
HYDROLOGY, RIVER REGIME & MORPHOLOGY
LOWER STIKINE RIVER TEST REACH
CROSS - SECTIONS - SHEET 1 OF 2

DATE AUG 1980	PLATE 5 - 7	R
DWN SMD	DWG No. 915 - C14 - U204	


75
74
73
72
71
70
69
68
67
66
65
64
63
ELEVATION IN METRES
0.2 %
0.5 %
1.0 %
2.0 %
5.0 %
10.0 %
20.0 %
30.0 %
40.0 %
50.0 %
0.5 %
1.0 %
0.2 %
5.0 %
2.0 %
10.0 %
30.0 %
50.0 %
20.0 %
40.0 %

SECTION LS - 4


70
69
68
67
66
65
64
63
62
61
60
ELEVATION IN METRES
0.2 %
1.0 %
0.5 %
2.0 %
5.0 %
10.0 %
20.0 %
30.0 %
40.0 %
50.0 %
0.5 %
1.0 %
0.2 %
5.0 %
2.0 %
10.0 %
30.0 %
20.0 %
40.0 %
50.0 %

SECTION LS - 5

NOTE:

WATER LEVELS SHOWN ARE FOR FLOWS
OF INDICATED EXCEEDANCE PROBABILITIES
DERIVED FROM FLOW DURATION ANALYSIS.

LEGEND

░ *Pre-project*

▒ *Post-project*

Horizontal Scale: 50 0 50 100 150 *Metres*

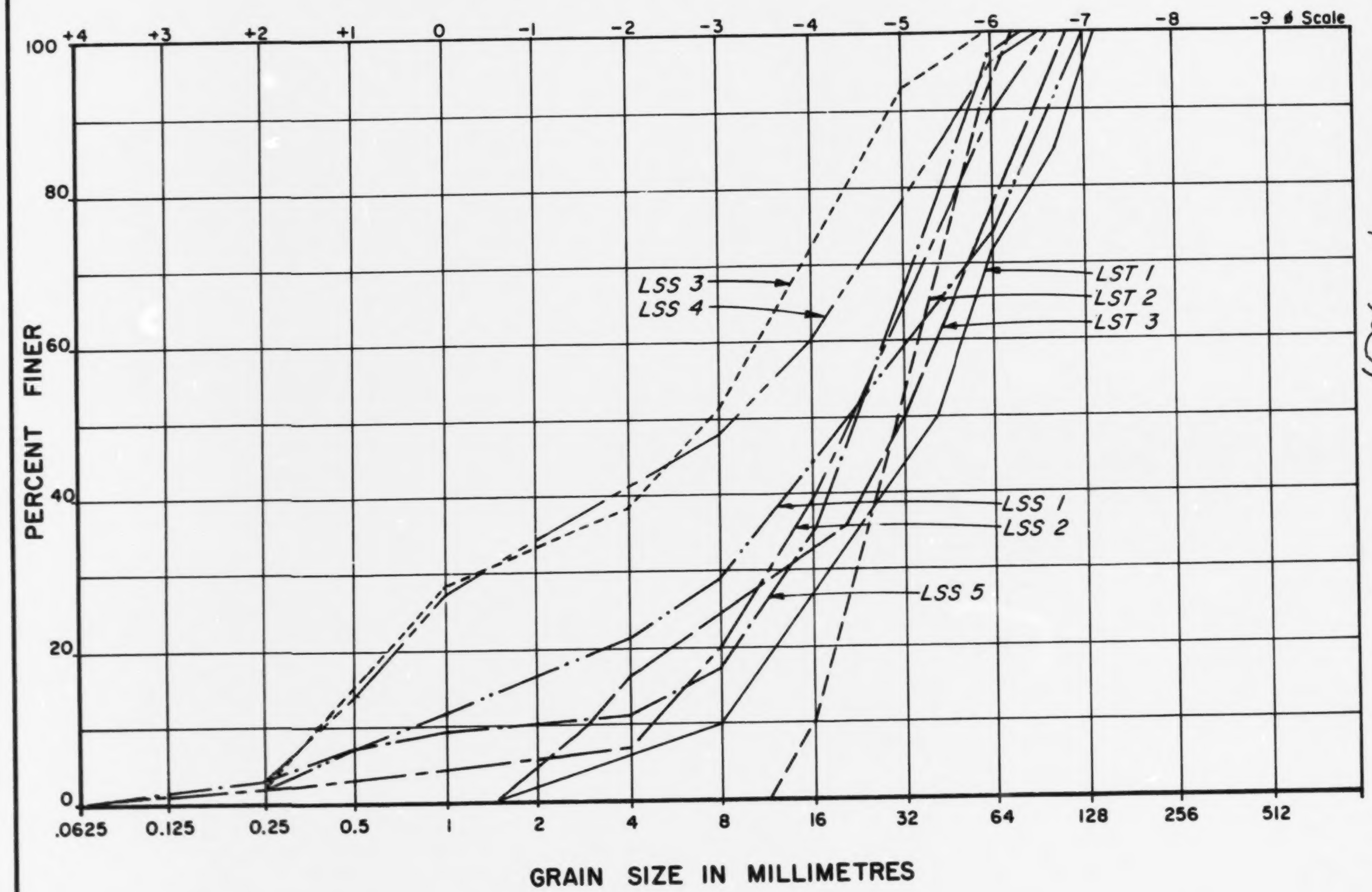
BRITISH COLUMBIA HYDRO AND POWER AUTHORITY

STIKINE - ISKUT FEASIBILITY STUDY

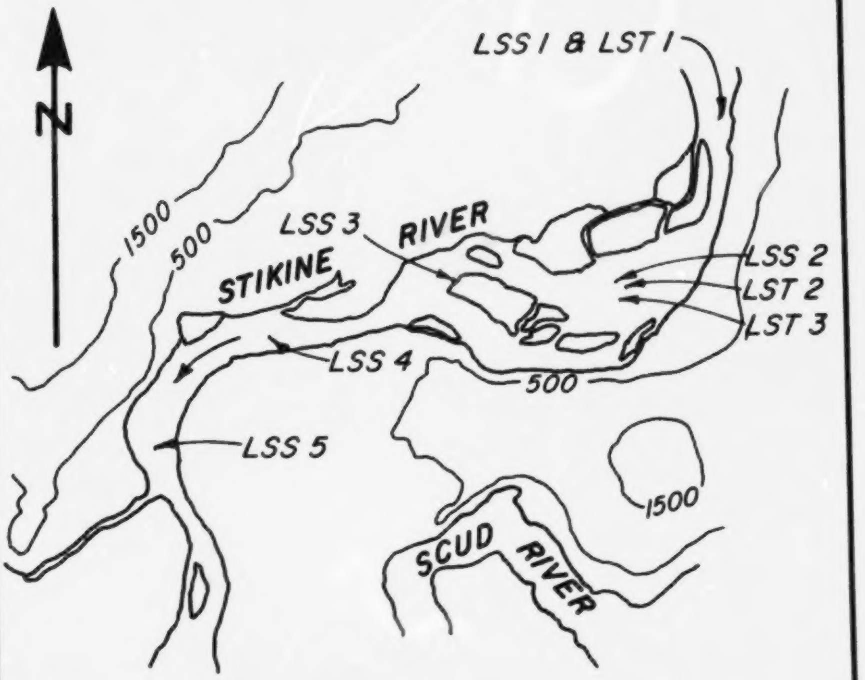
HYDROLOGY, RIVER REGIME & MORPHOLOGY
LOWER STIKINE RIVER TEST REACH
CROSS - SECTIONS - SHEET 2 OF 2

DATE AUG 1980	PLATE 5 - 7	R
DWN SMD	DWG No. 915 - C14 - D205	

REPORT No. H-1110



LOWER STIKINE RIVER


N
LSS 1 & LST 1
1500
500
LSS 3
RIVER
STIKINE
LSS 2
LST 2
LST 3
LSS 4
500
LSS 5
1500
SCUD
RIVER

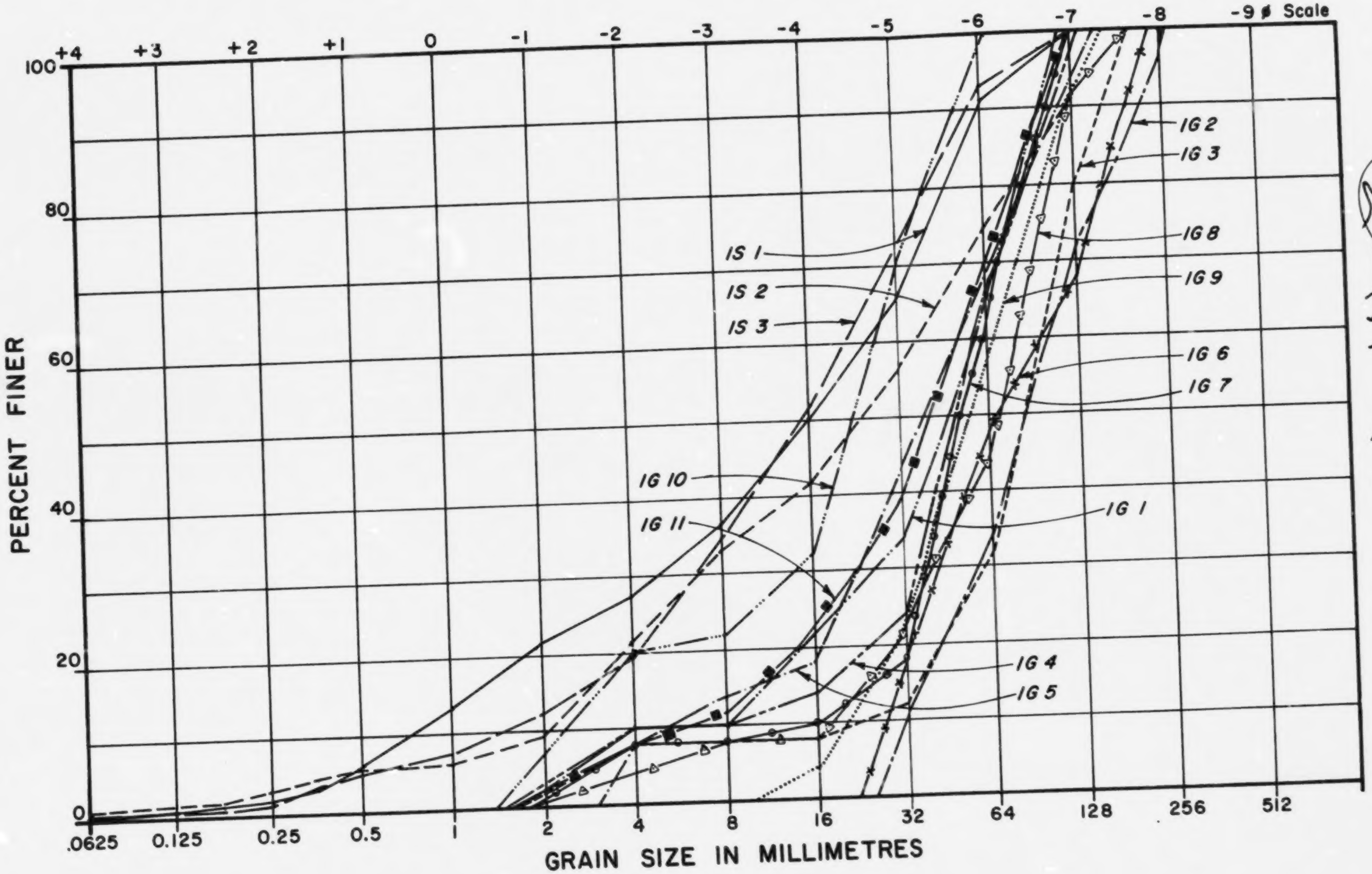
KEY PLAN
NTS

BRITISH COLUMBIA HYDRO AND POWER AUTHORITY

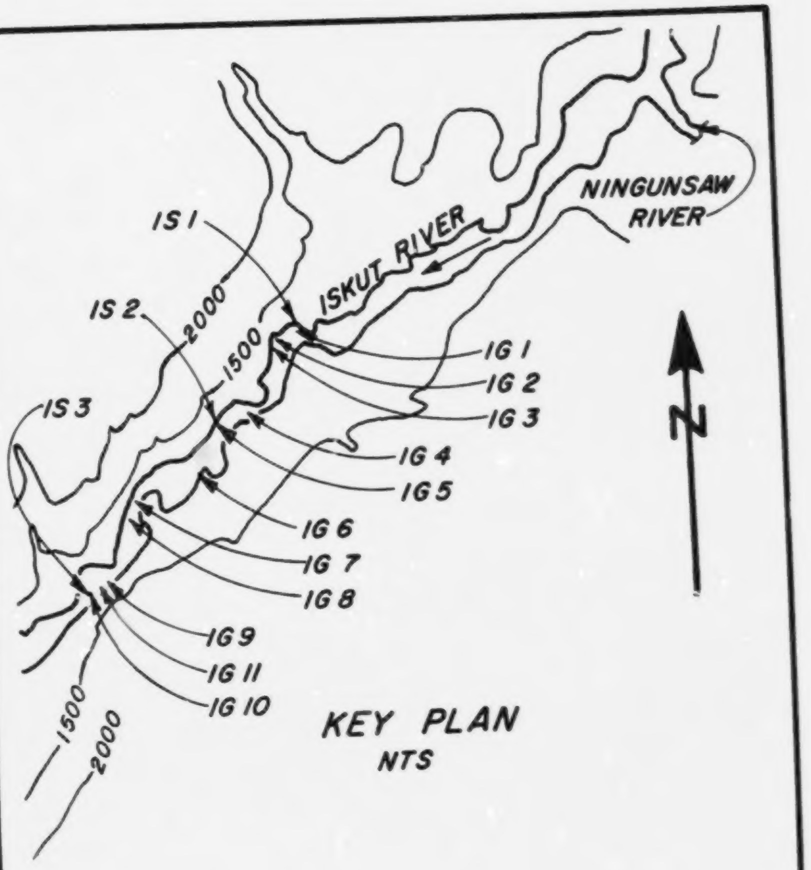
STIKINE – ISKUT FEASIBILITY STUDY
HYDROLOGY, RIVER REGIME & MORPHOLOGY
GRAINSIZE DISTRIBUTION
BED MATERIAL – SHEET 1 OF 7

DATE AUG 1980	PLATE 5 - 8
DWN A H	DWG. No. 915 - C14 - B206

REPORT No. H-1110



UPPER ISKUT RIVER



NINGUNSAW RIVER
ISKUT RIVER
IS 1
IS 2
IS 3
2000
1500
IG 1
IG 2
IG 3
IG 4
IG 5
IG 6
IG 7
IG 8
IG 9
IG 11
IG 10
1500
2000
N

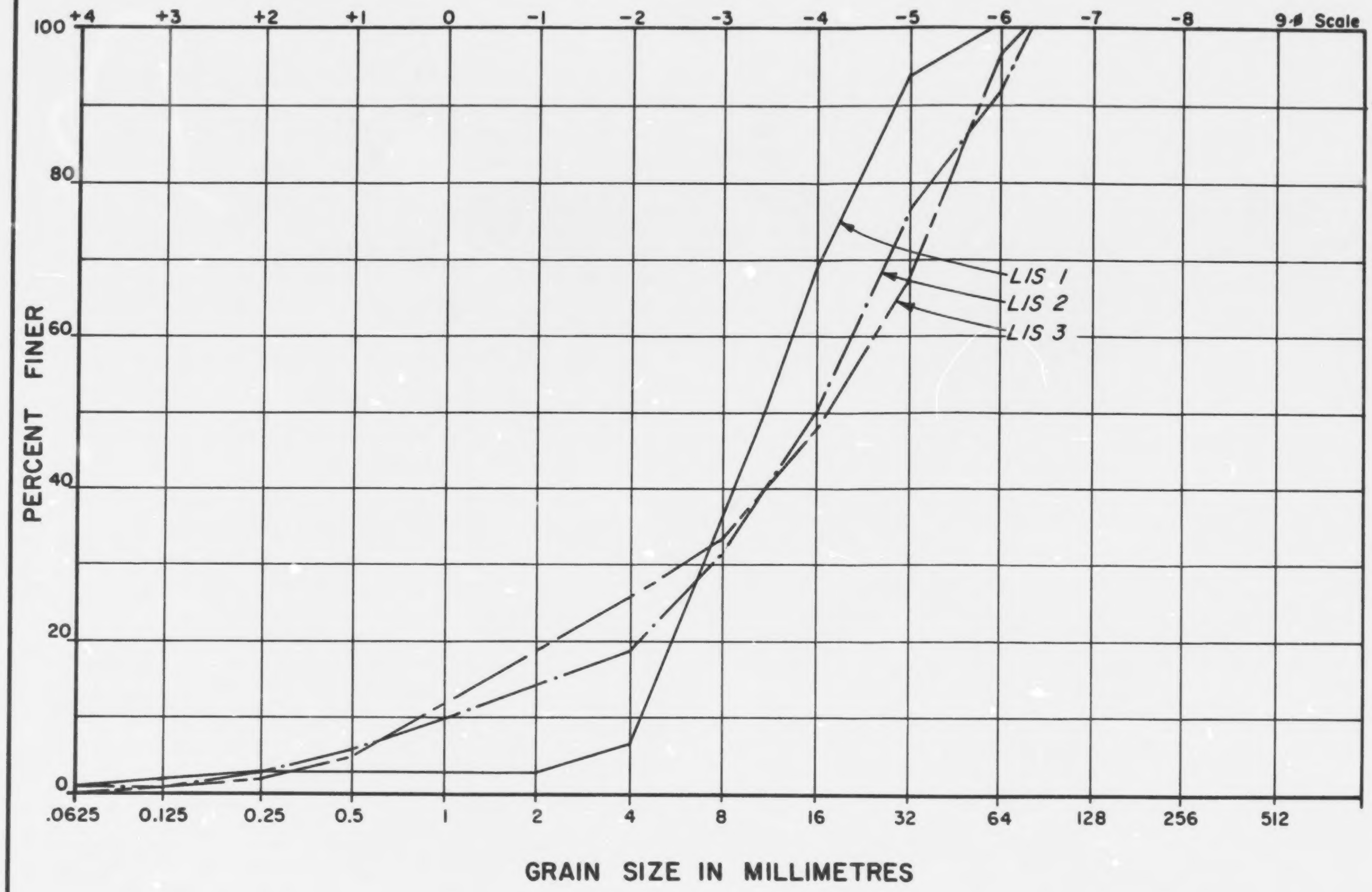
KEY PLAN
NTS

BRITISH COLUMBIA HYDRO AND POWER AUTHORITY

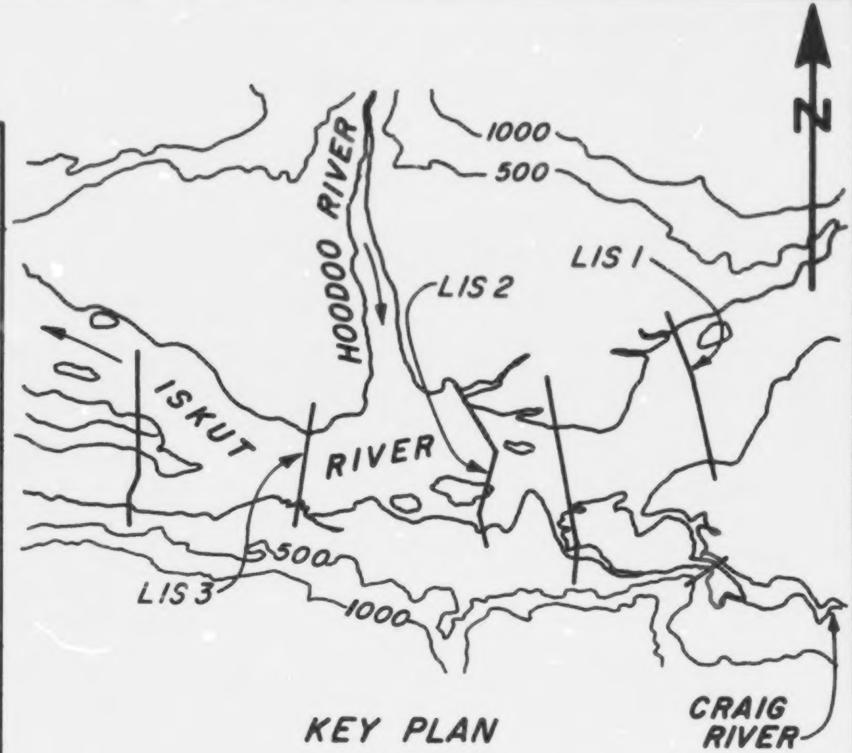
STIKINE - ISKUT FEASIBILITY STUDY
HYDROLOGY, RIVER REGIME & MORPHOLOGY
GRAINSIZE DISTRIBUTION
BED MATERIAL - SHEET 2 OF 7

DATE AUG 1980	PLATE 5 - 8
DWN SMD	DWG. No 915 - C14 - B207

REPORT No H-1110



LOWER ISKUT RIVER


N
1000
500
HOODOO RIVER
LIS 1
LIS 2
ISKUT
RIVER
LIS 3
500
1000
CRAIG RIVER

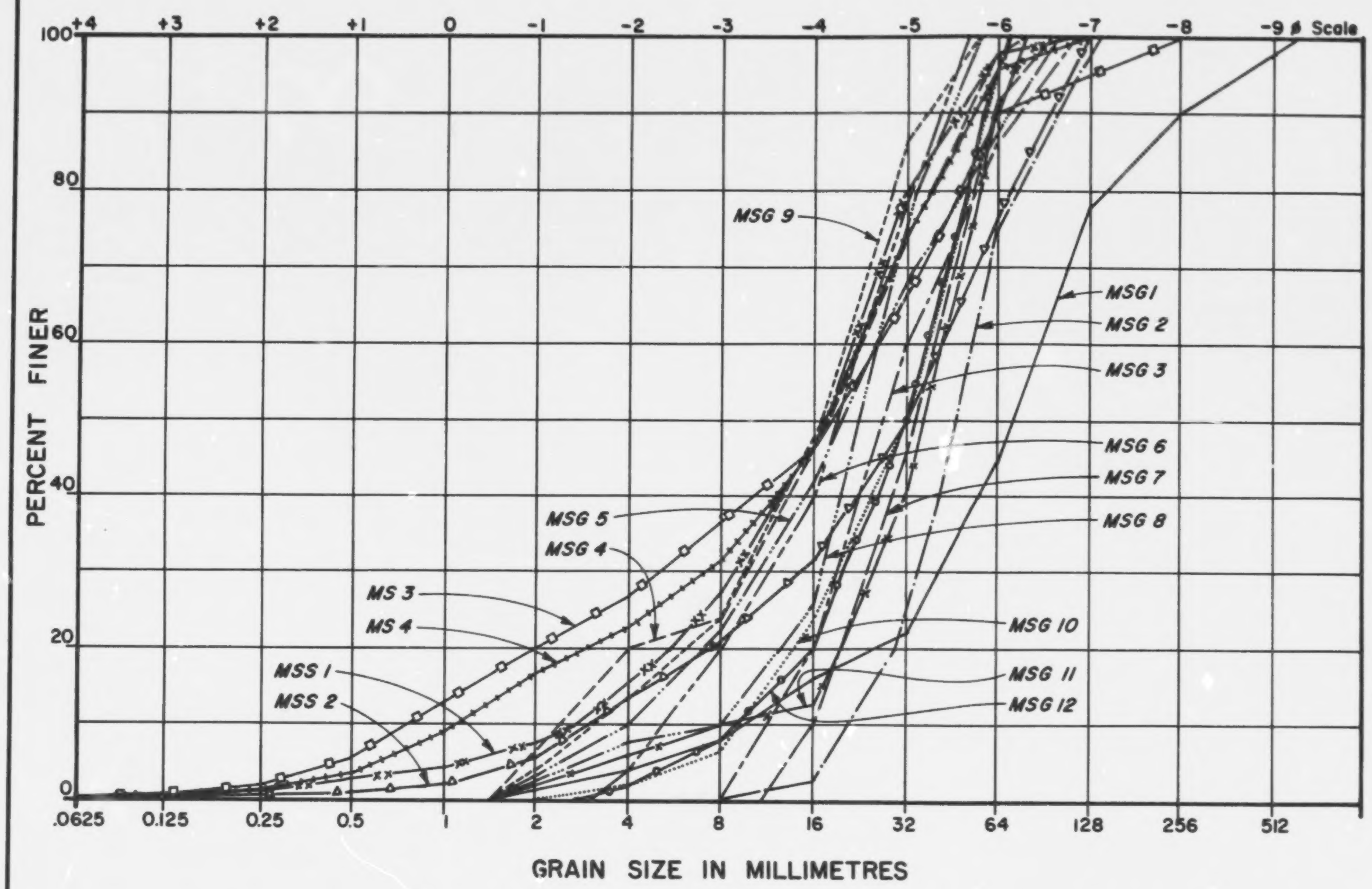
KEY PLAN
NTS

BRITISH COLUMBIA HYDRO AND POWER AUTHORITY

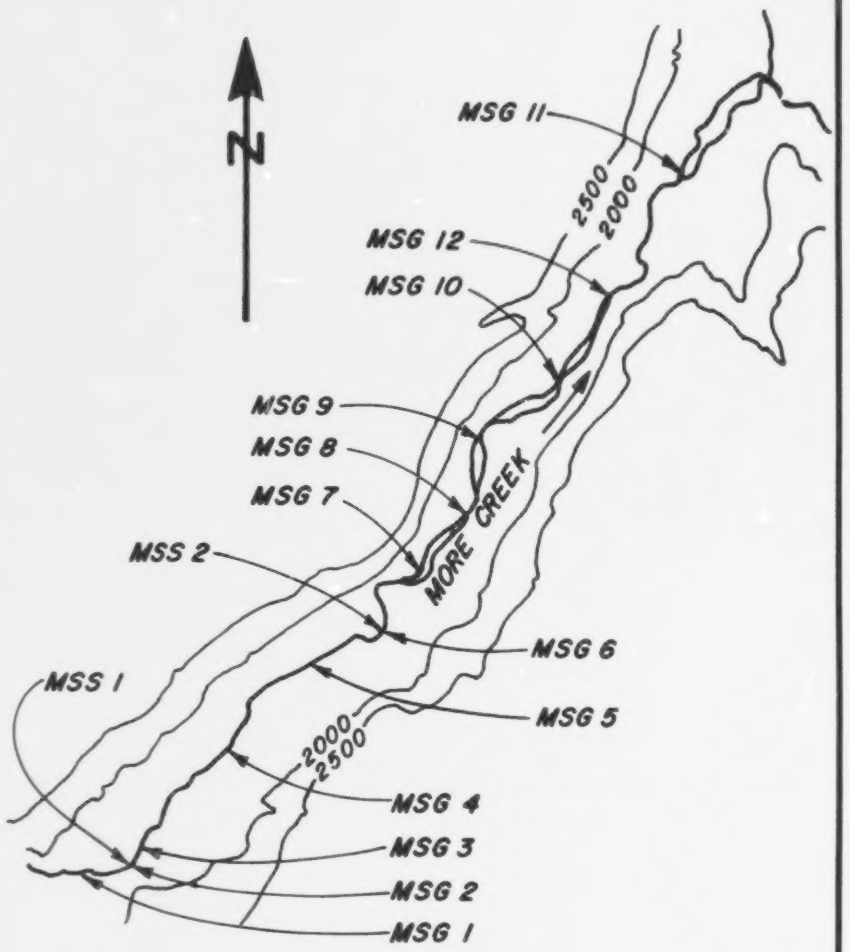
STIKINE – ISKUT FEASIBILITY STUDY
HYDROLOGY, RIVER REGIME & MORPHOLOGY
GRAINSIZE DISTRIBUTION
BED MATERIAL – SHEET 3 OF 7

DATE AUG 1980
PLATE 5 - 8
DWN AH
DWG. No. 915 - C14 - B208

REPORT No H-1110



MORE CREEK (SOUTH)



N
MSG 11
MSG 12
MSG 10
2500
2000
MSG 9
MSG 8
MSG 7
MORE CREEK
MSS 2
MSG 6
MSS 1
MSG 5
2000
2500
MSG 4
MSG 3
MSG 2
MSG 1

KEY PLAN

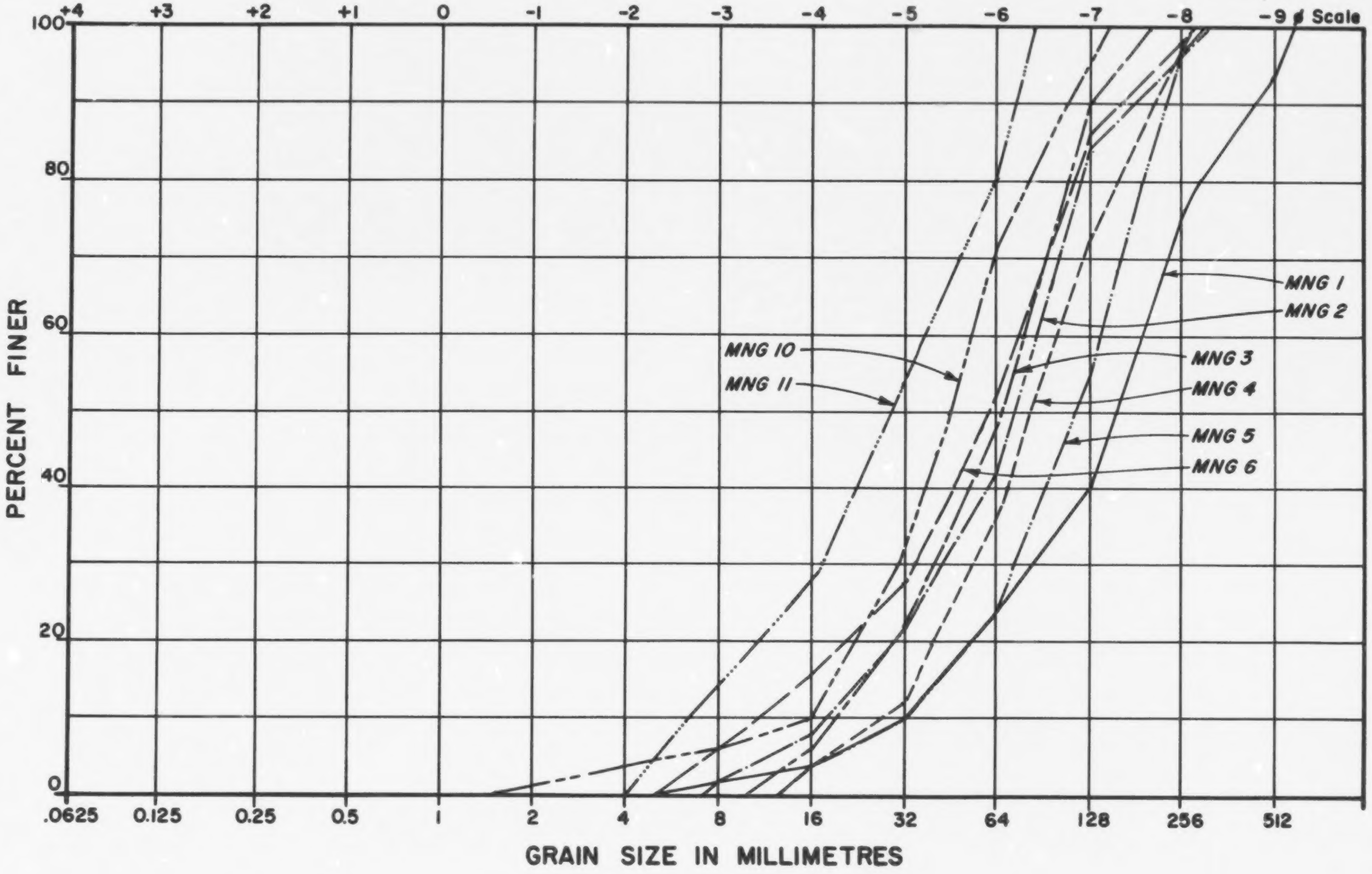
NTS

BRITISH COLUMBIA HYDRO AND POWER AUTHORITY

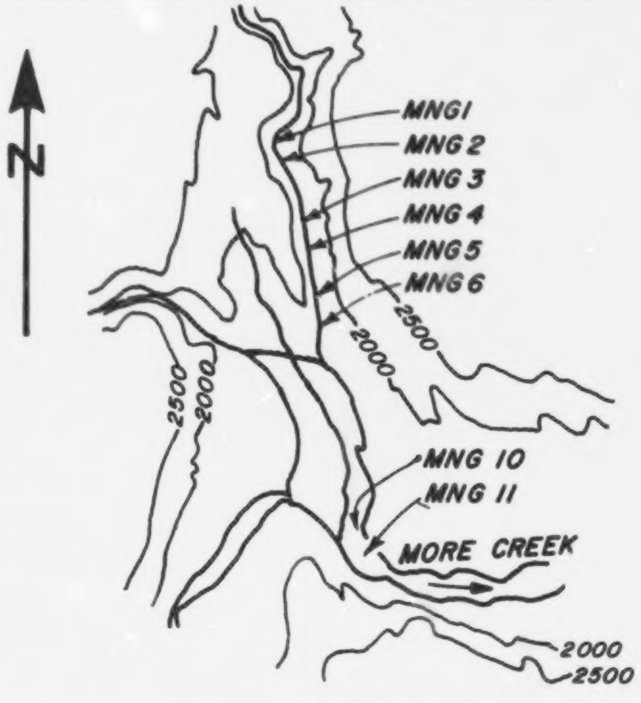
STIKINE - ISKUT FEASIBILITY STUDY
HYDROLOGY, RIVER REGIME & MORPHOLOGY
GRAINSIZE DISTRIBUTION
BED MATERIAL - SHEET 4 OF 7

DATE AUG 1980	PLATE 5 - 8
DWN SMD	DWG. No 915 - C14 - B209

REPORT No H-1110



MORE CREEK (NORTH)

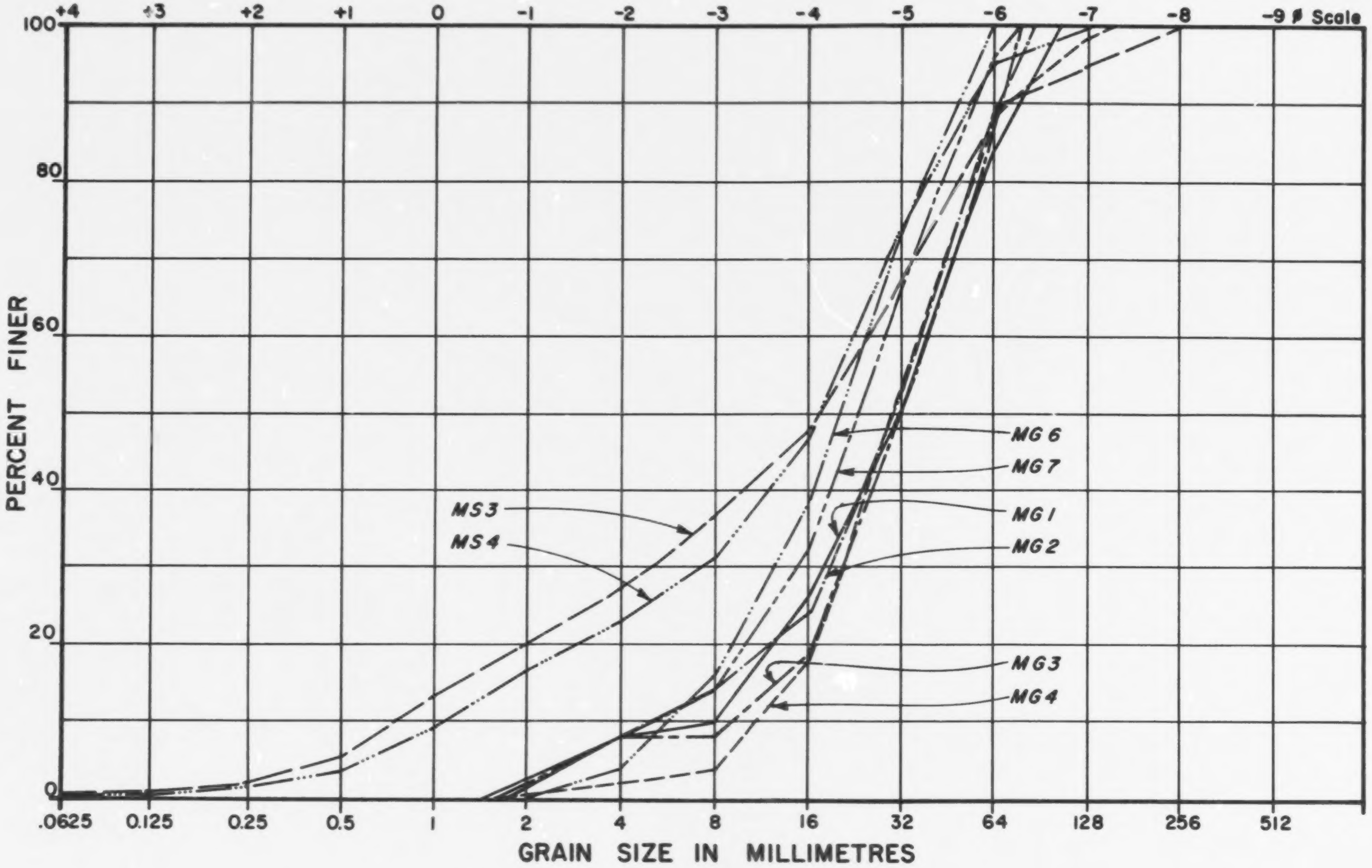

N
MNG1
MNG 2
MNG 3
MNG 4
MNG 5
MNG 6
MNG 10
MNG 11
MORE CREEK
2500
2000
2000
2500
2500
2000
2000
2500

KEY PLAN
NTS

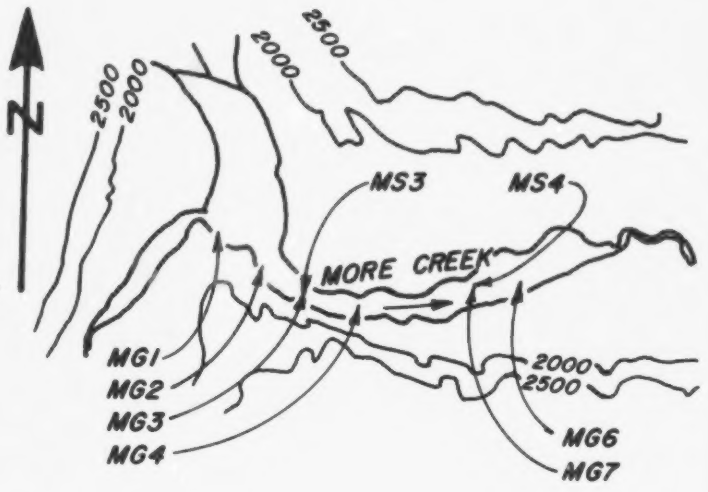
BRITISH COLUMBIA HYDRO AND POWER AUTHORITY

STIKINE - ISKUT FEASIBILITY STUDY
HYDROLOGY, RIVER REGIME & MORPHOLOGY
GRAINSIZE DISTRIBUTION
BED MATERIAL - SHEET 5 OF 7

DATE AUG 1980
PLATE 5 - 8
DWN SMD
DWG. No. 915 - C14 - B210
REPORT No. H-1110



MORE CREEK



N
2500
2000
2000
2500
MS3
MS4
MORE CREEK
MG1
MG2
MG3
MG4
2000
2500
MG6
MG7

KEY PLAN

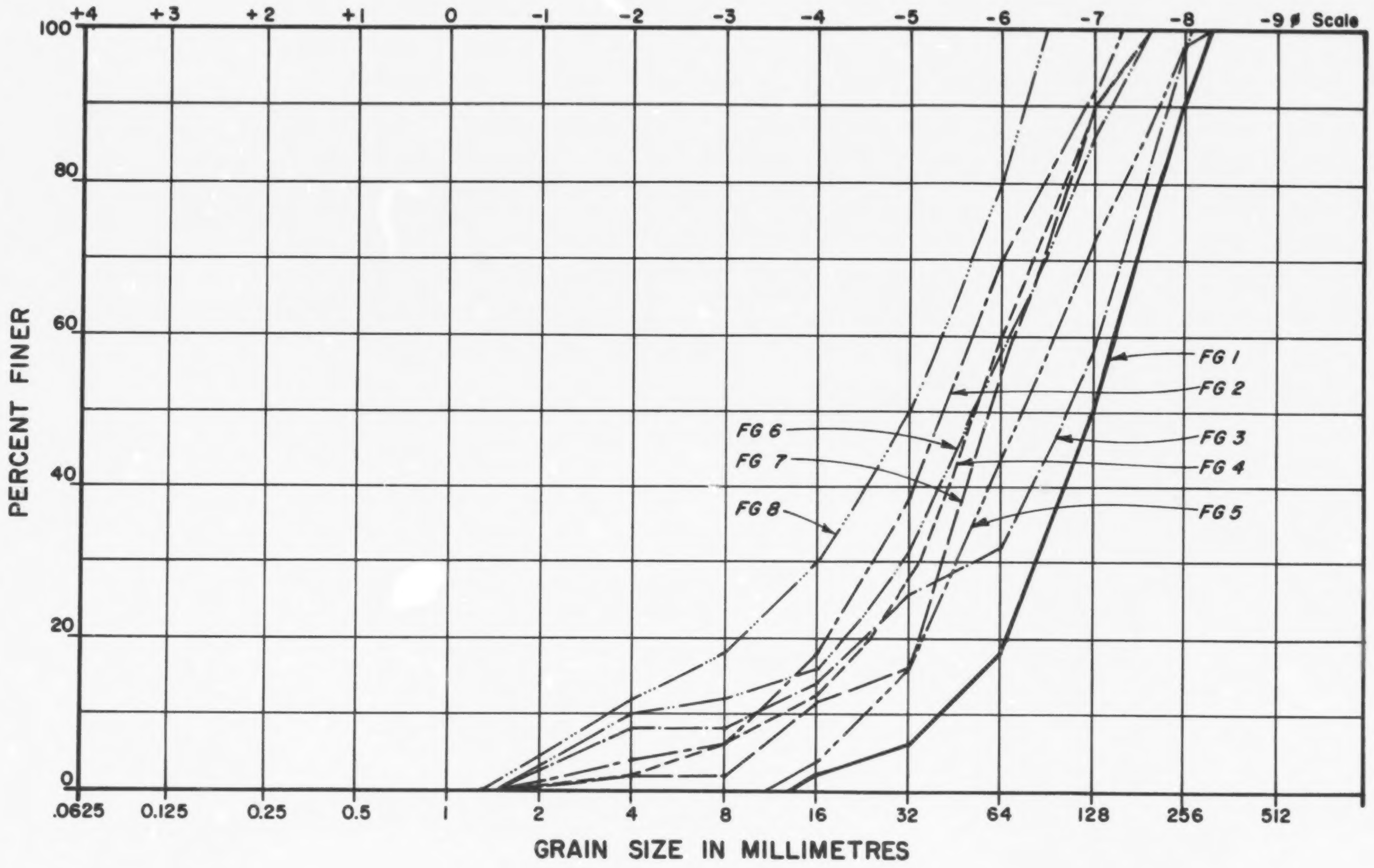
NTS

BRITISH COLUMBIA HYDRO AND POWER AUTHORITY

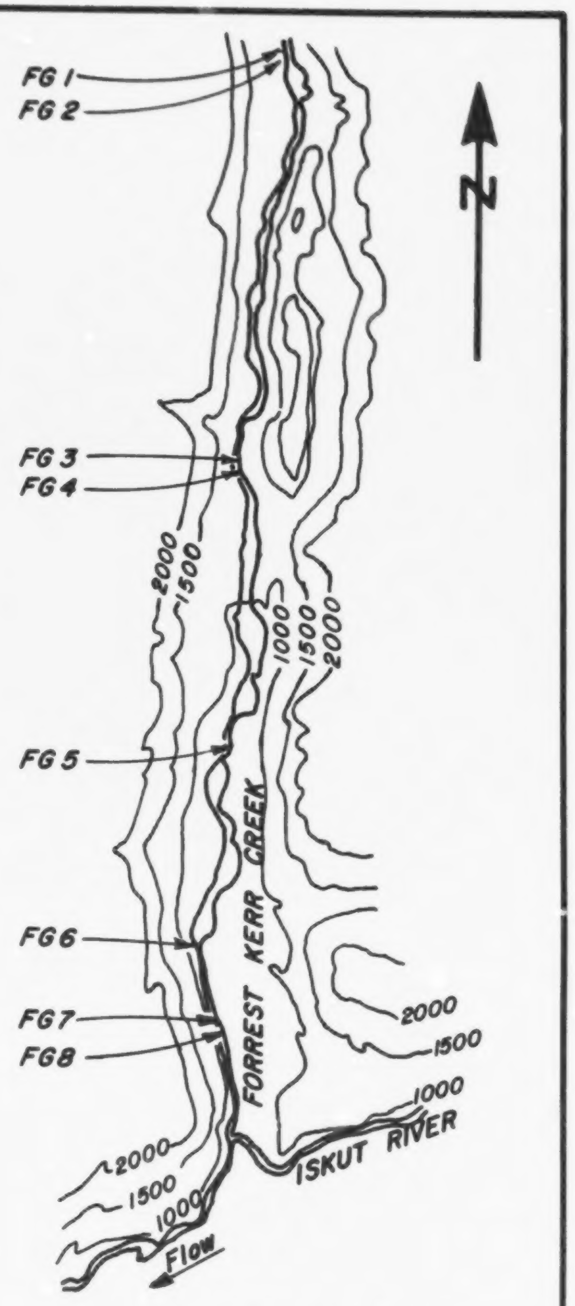
STIKINE - ISKUT FEASIBILITY STUDY
HYDROLOGY, RIVER REGIME & MORPHOLOGY
GRAINSIZE DISTRIBUTION
BED MATERIAL - SHEET 6 OF 7

DATE AUG 1980	PLATE 5-8
DWN SMD	DWG. No. 915 - C14 - B211

REPORT No H-1110



FORREST KERR CREEK

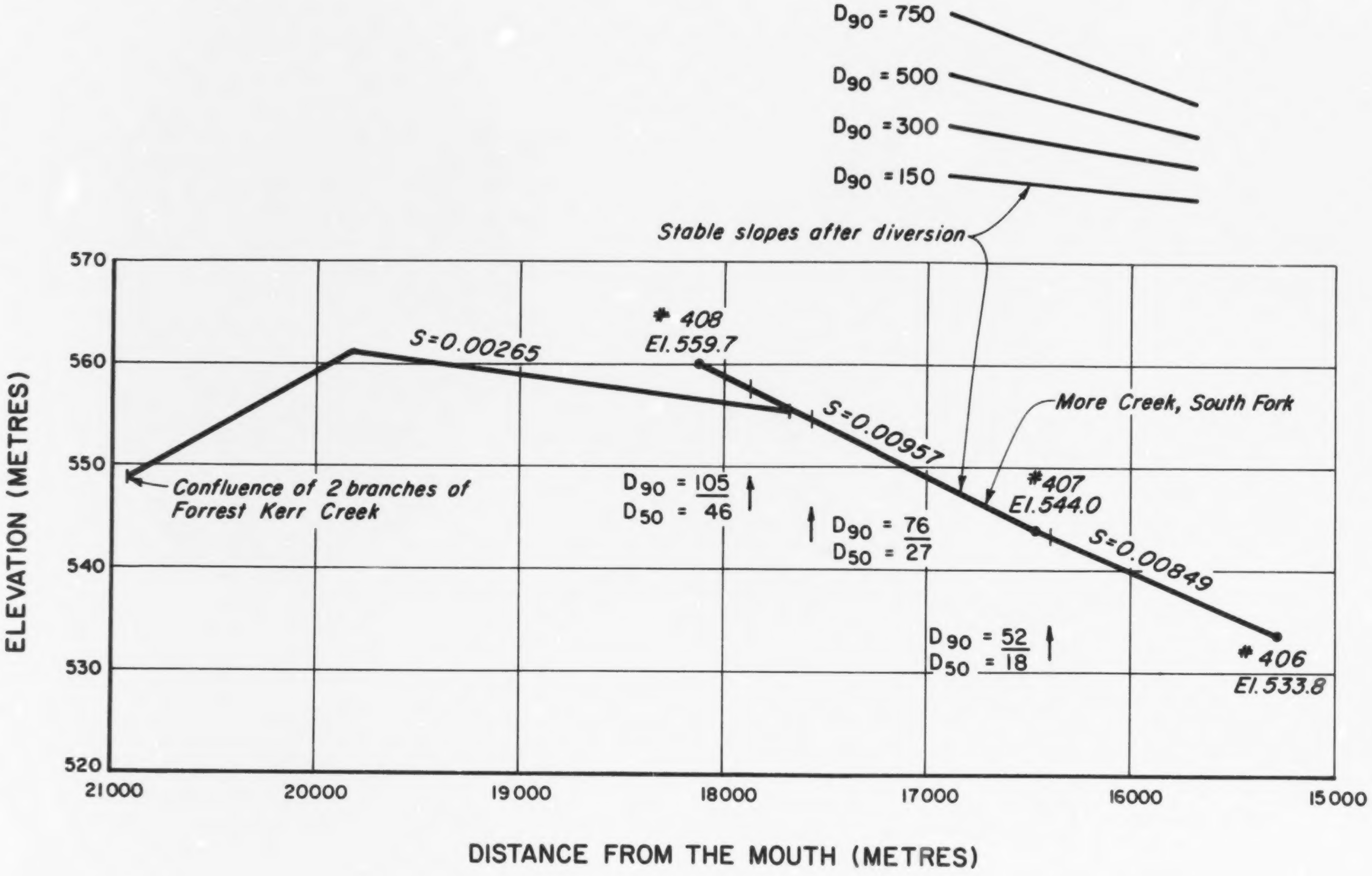

FG 1
FG 2
FG 3
FG 4
FG 5
FG 6
FG 7
FG 8
N
2000
1500
1000
0
FORREST KERR CREEK
ISKUT RIVER
Flow

KEY PLAN
NTS

BRITISH COLUMBIA HYDRO AND POWER AUTHORITY

STIKINE - ISKUT FEASIBILITY STUDY
HYDROLOGY, RIVER REGIME & MORPHOLOGY
GRAINSIZE DISTRIBUTION
BED MATERIAL - SHEET 7 OF 7

DATE AUG 1980
PLATE 5 - 8
DWN SMD
DWG. No. 915 - C14 - B212
REPORT No. H-1110



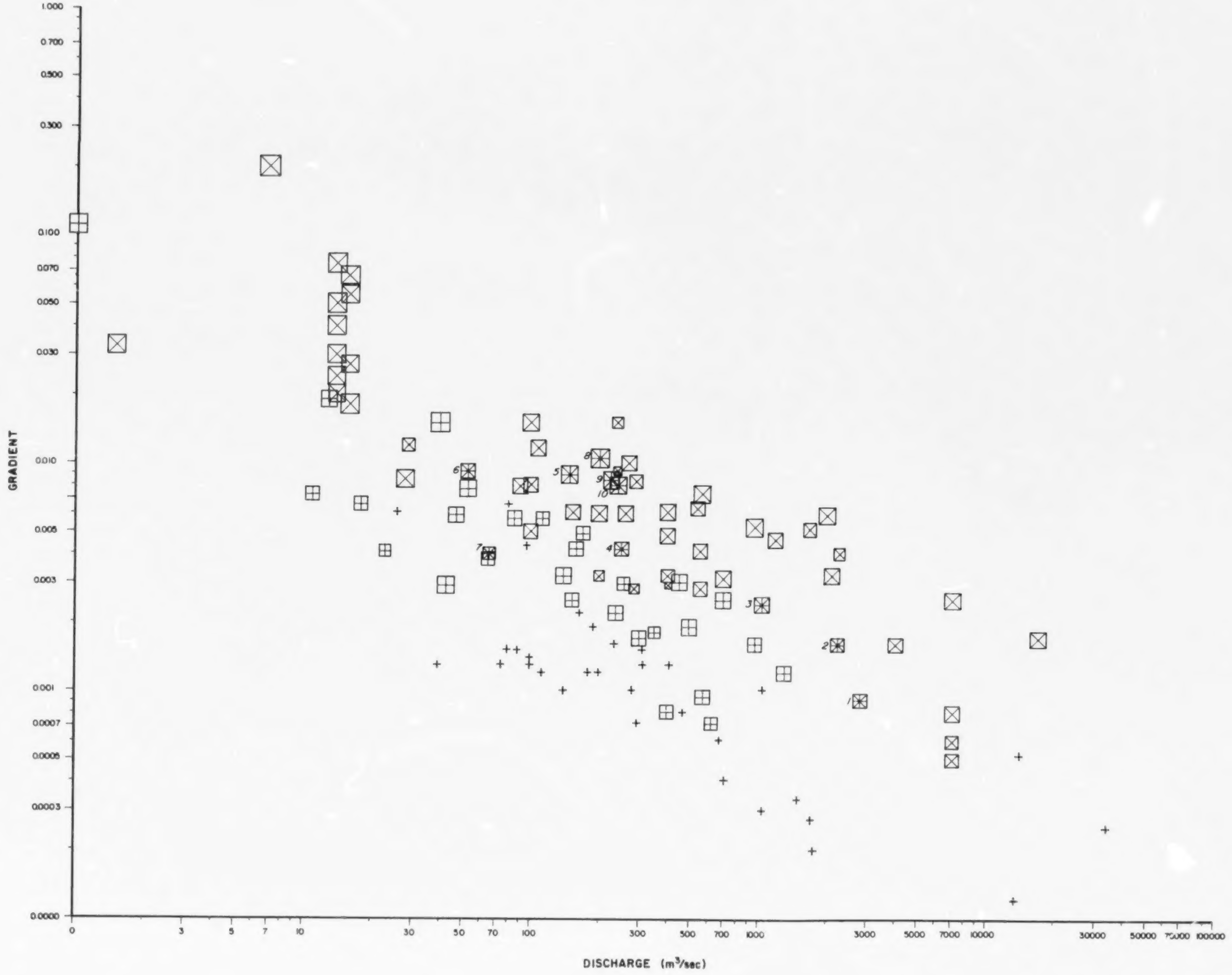
BRITISH COLUMBIA HYDRO AND POWER AUTHORITY

STIKINE - ISKUT FEASIBILITY STUDY

HYDROLOGY, RIVER REGIME & MORPHOLOGY
FORREST KERR CREEK DIVERSION PROFILE

DATE AUG 1980	**PLATE 5-9**
DWN G.C.	DWG. No 915 - C14 - C213

REPORT No. H-1110



NOTE:

1. DATA FROM ASSORTED RIVERS IN NEW ZEALAND, INDIA, PAKISTAN AND CANADA FOR WHICH APPROPRIATE DATA WAS AVAILABLE.
2. EXCEPT FOR SAND-BED RIVERS THE SYMBOL WIDTH IS PROPORTIONAL TO THE LOG OF THE GRAIN SIZE (AS MEASURED BY D90 VALUE)
3. DISCHARGE VALUE IS THE ESTIMATED TWO-YEAR FLOOD, ESTIMATED "DOMINATE DISCHARGE" OR ESTIMATED "BANKFULL DISCHARGE" IN THAT ORDER OF PREFERENCE.

LEGEND

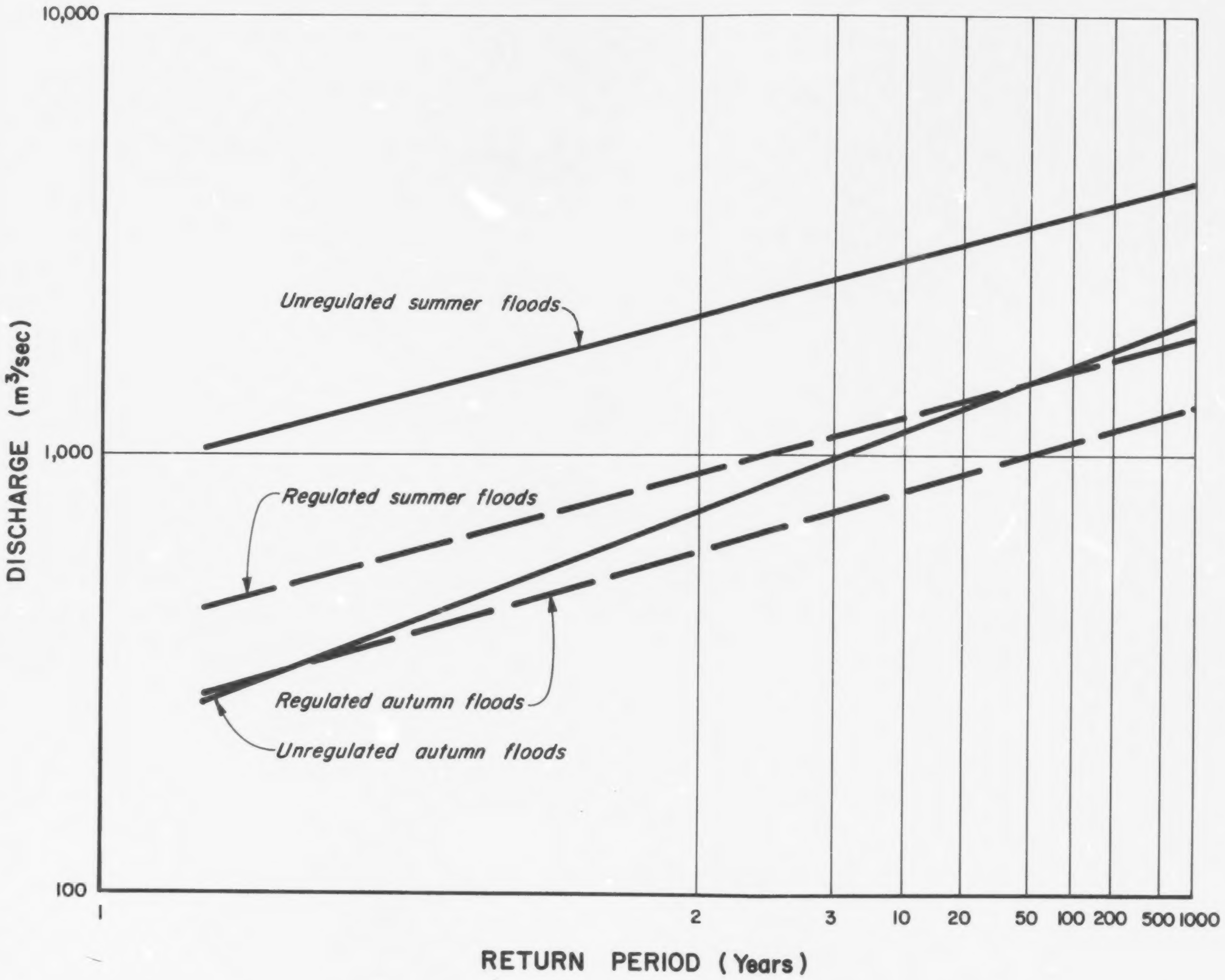
☒	BRAIDED GRAVEL-BED CHANNEL
⊞	WANDERING CHANNEL
+	BRAIDED SAND-BED CHANNEL
▩	LOCATED IN STIKINE RIVER BASIN
1.	LOWER STIKINE TEST REACH
2.	LOWER ISKUT TEST REACH
3.	UPPER ISKUT TEST REACH
4.	MORE CREEK (MAIN CHANNEL)
5.	MORE CREEK TEST REACH
6-7.	MORE CREEK (SOUTH BRANCH)
8, 9-10	FORREST KERR CREEK

BRITISH COLUMBIA HYDRO AND POWER AUTHORITY

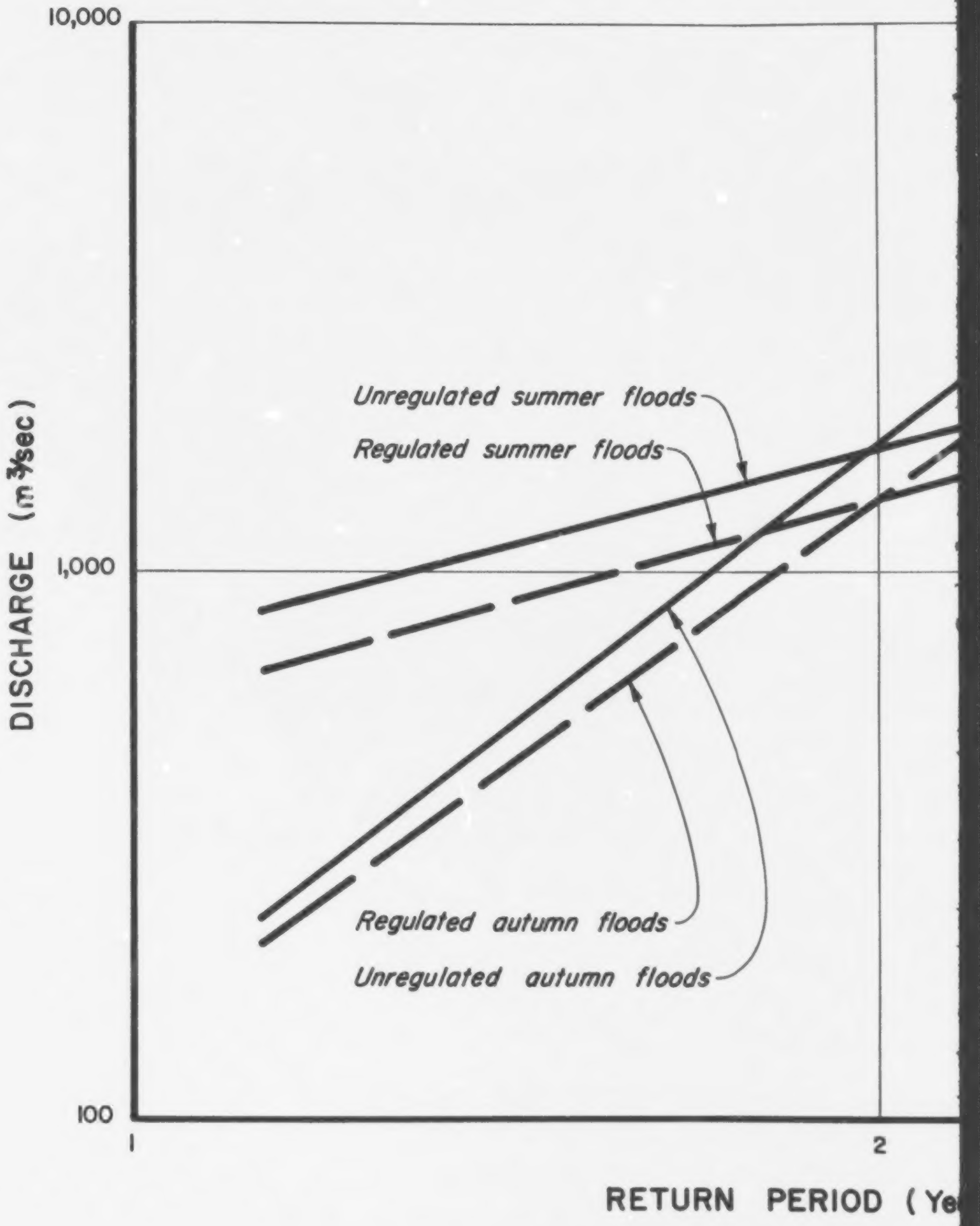
STIKINE - ISKUT FEASIBILITY STUDY
HYDROLOGY, RIVER REGIME & MORPHOLOGY
DISCHARGE, SLOPE AND GRAINSIZE DATA
FOR BRAIDED RIVERS

DATE AUG 1980	PLATE 5-10	R
DWN K.L.	DWG No. 915 - C14 - D214	

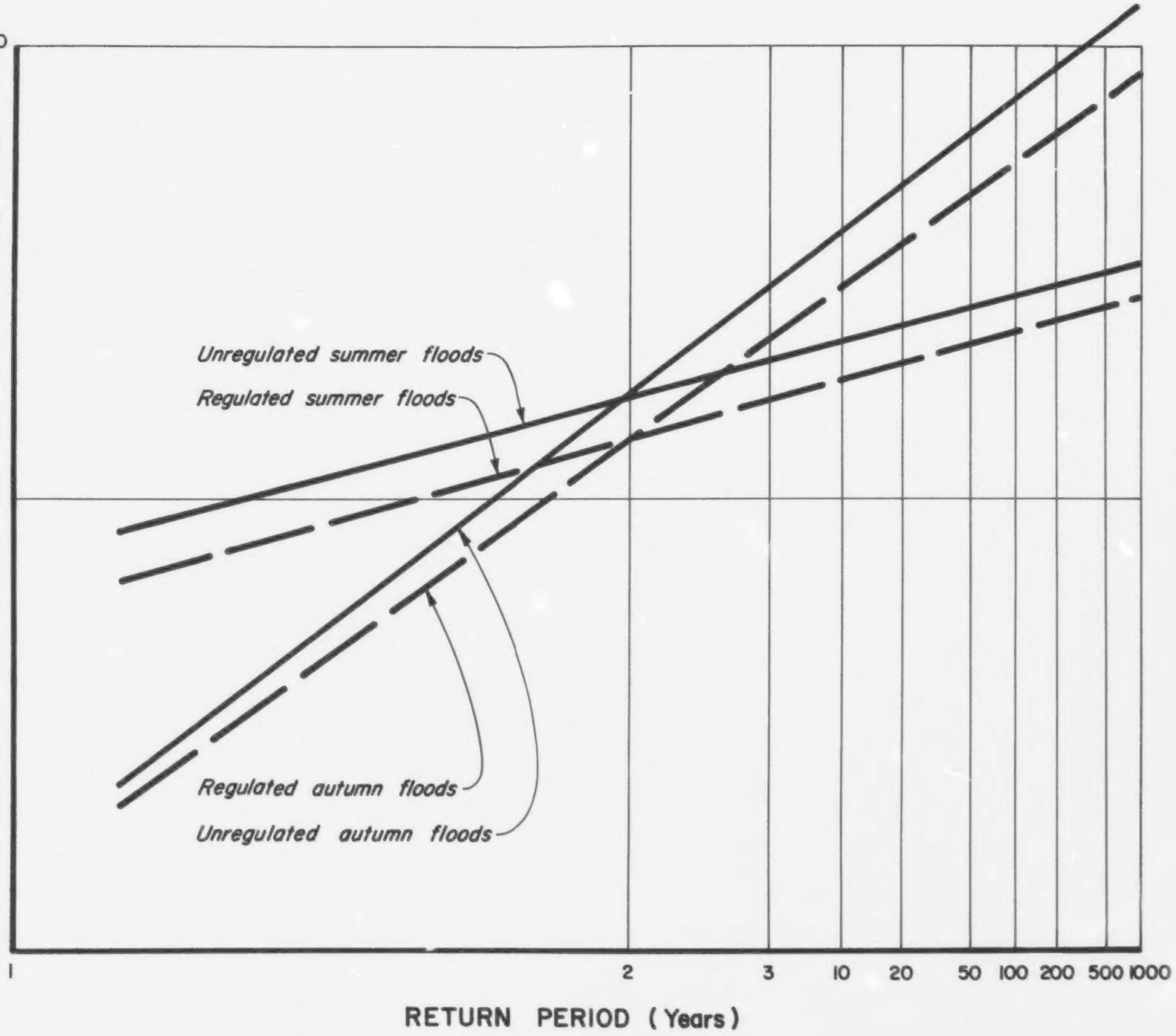
REPORT No. H-1110



STIKINE RIVER AT TELEGRAPH CREEK
1967 - 1978



ISKUT RIVER BELOW JOHN
1972 - 1978



ISKUT RIVER BELOW JOHNSON RIVER

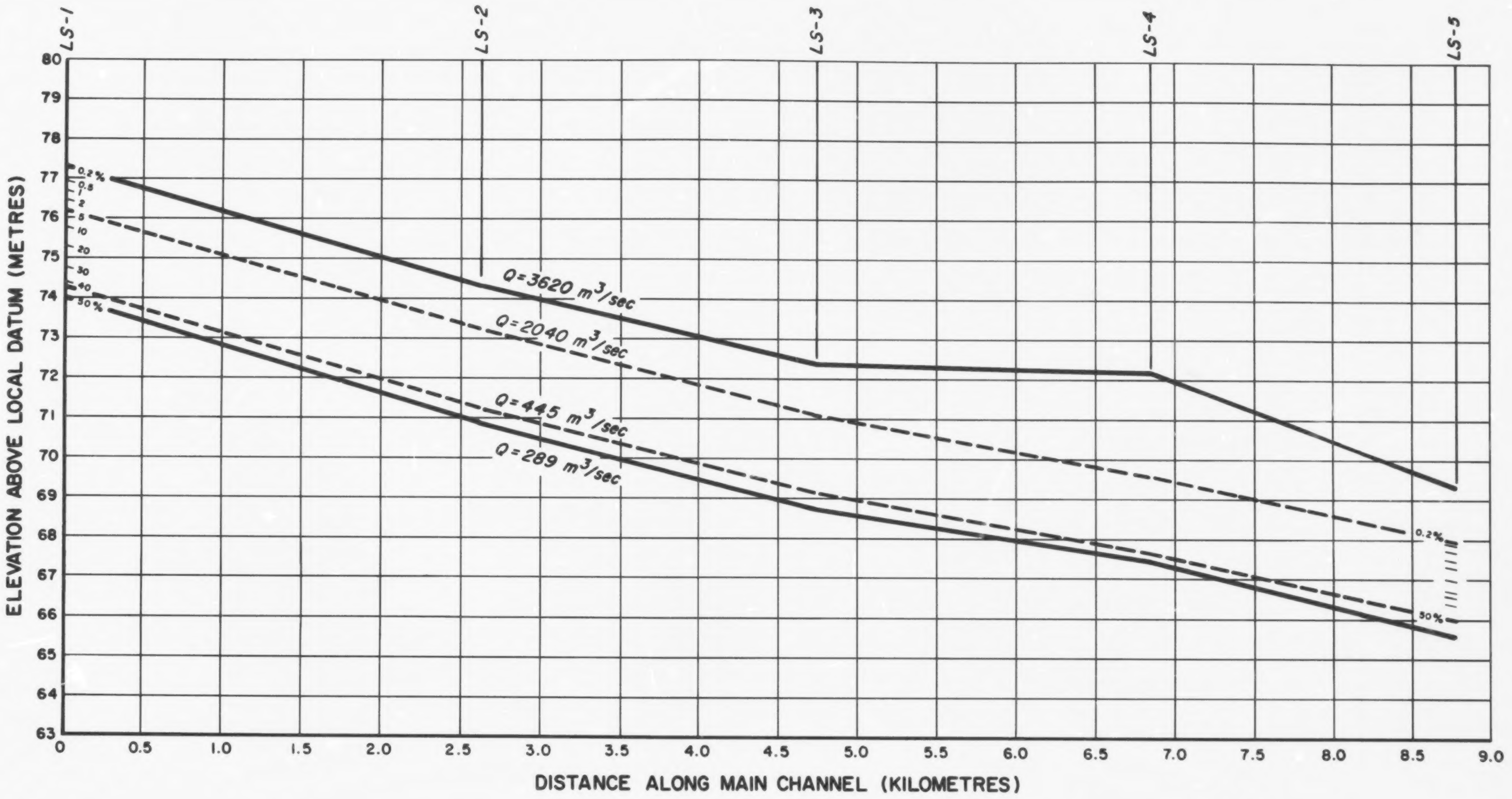
1972 - 1978

BRITISH COLUMBIA HYDRO AND POWER AUTHORITY

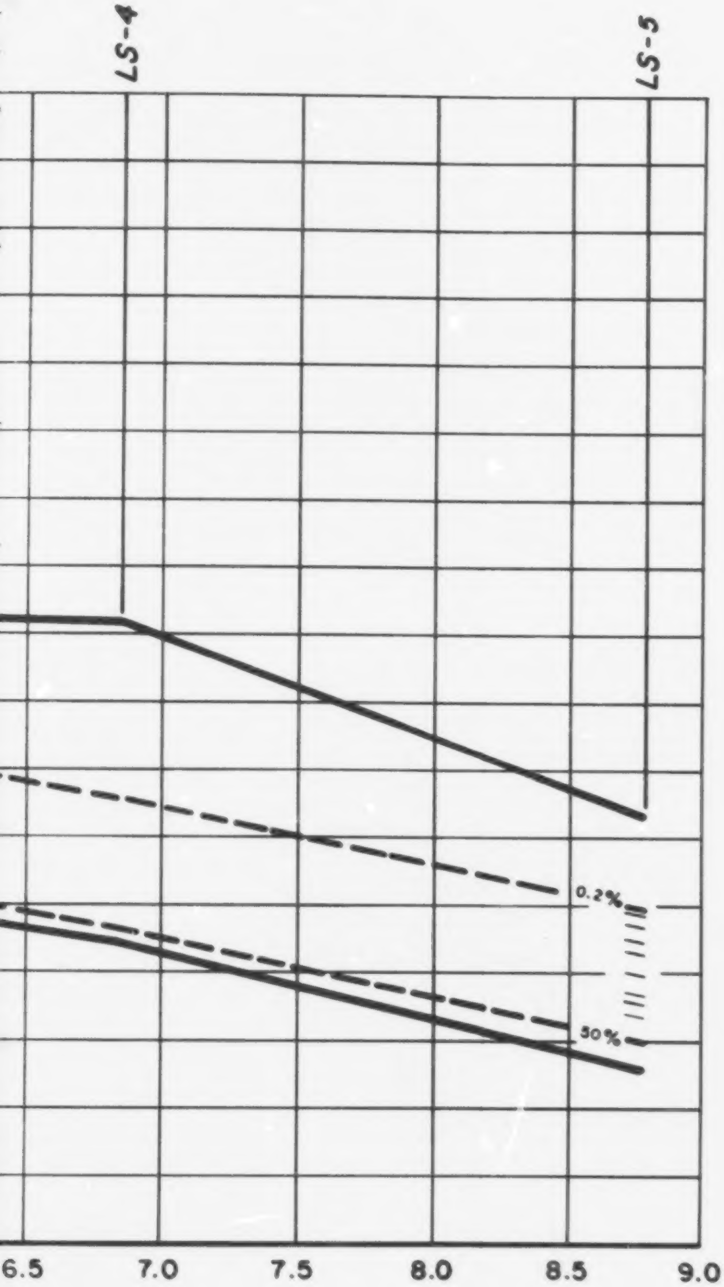
STIKINE - ISKUT FEASIBILITY STUDY
HYDROLOGY, RIVER REGIME & MORPHOLOGY
POST - PROJECT FLOOD FREQUENCY CURVES

DATE AUG 1980	**PLATE 5 - 11**
DWN K.L.	DWG. No. 915 - C14 - C215

REPORT No H-1110



LOWER STIKINE RIVER TEST REACH



NOTES:

1. FOR TEST REACH LOCATION SEE PLATE 2-1.
2. FOR CROSS SECTION LOCATION AND CONFIGURATION SEE PLATE 5-7.
3. WATER LEVELS SHOWN ARE FOR FLOWS OF INDICATED EXCEEDENCE PROBABILITIES DERIVED FROM FLOW DURATION ANALYSIS.

LEGEND:

━━━ NATURAL CONDITIONS

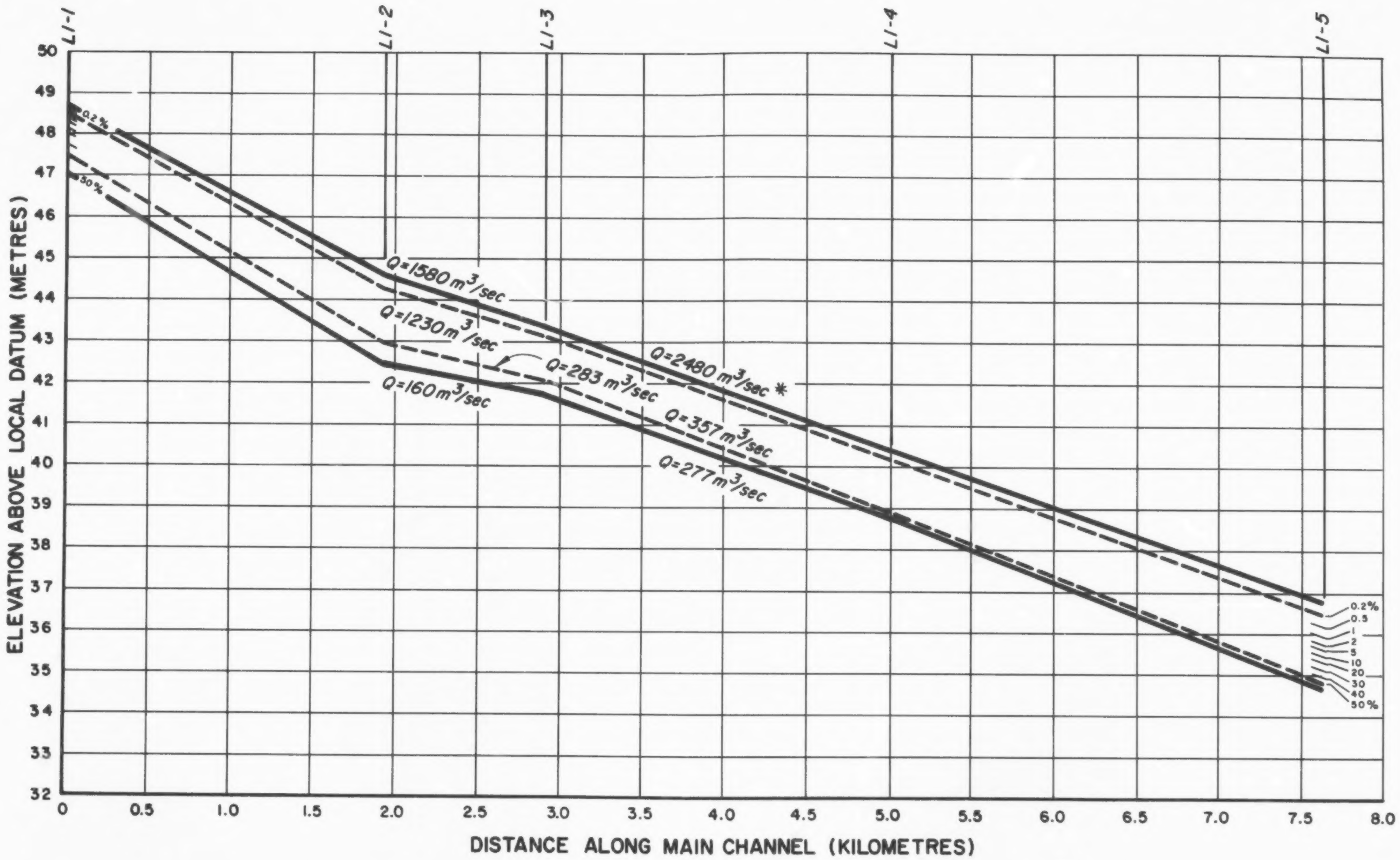
— — — REGULATED CONDITIONS

BRITISH COLUMBIA HYDRO AND POWER AUTHORITY

STIKINE - ISKUT FEASIBILITY STUDY
HYDROLOGY, RIVER REGIME & MORPHOLOGY
TEST REACH PROFILES
- SHEET 1 OF 4

DATE AUG 1980	PLATE 5 - 12
DWN C.Y.	DWG No. 915 - C14 - C216

REPORT No. H-1110



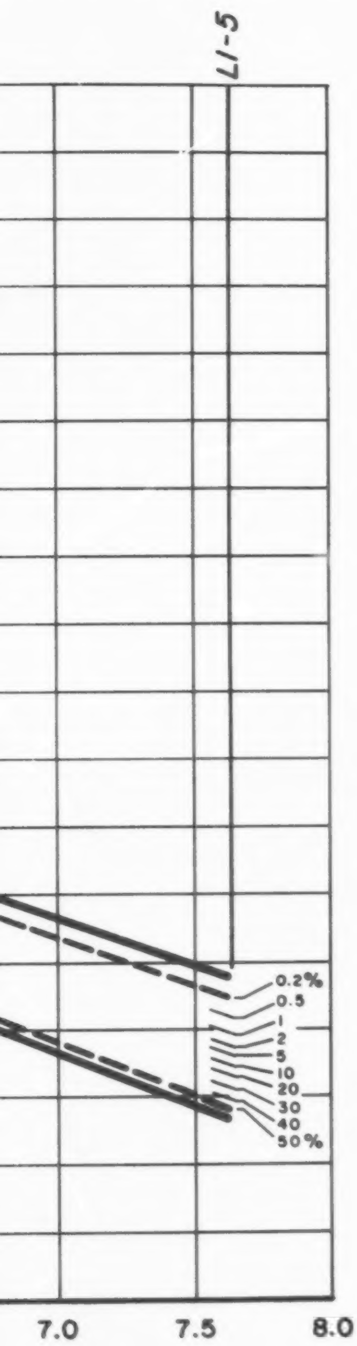
LOWER ISKUT RIVER TEST REACH

* *Tributary inflow from the Craig and Hoodoo rivers are introduced at Section L1-3.*

NOT
1.
2.
3.

LEG

BR
STI
HY
TE
DATE
DWN
REPOR



NOTE:

1. FOR TEST REACH LOCATION SEE PLATE 2-1
2. FOR CROSS SECTION LOCATION AND CONFIGURATION SEE PLATE 5-6
3. WATER LEVELS SHOWN ARE FOR FLOWS OF INDICATED EXCEEDENCE PROBABILITIES DERIVED FROM FLOW DURATION ANALYSIS

LEGEND:

——— NATURAL CONDITIONS

— — — REGULATED CONDITIONS

BRITISH COLUMBIA HYDRO AND POWER AUTHORITY

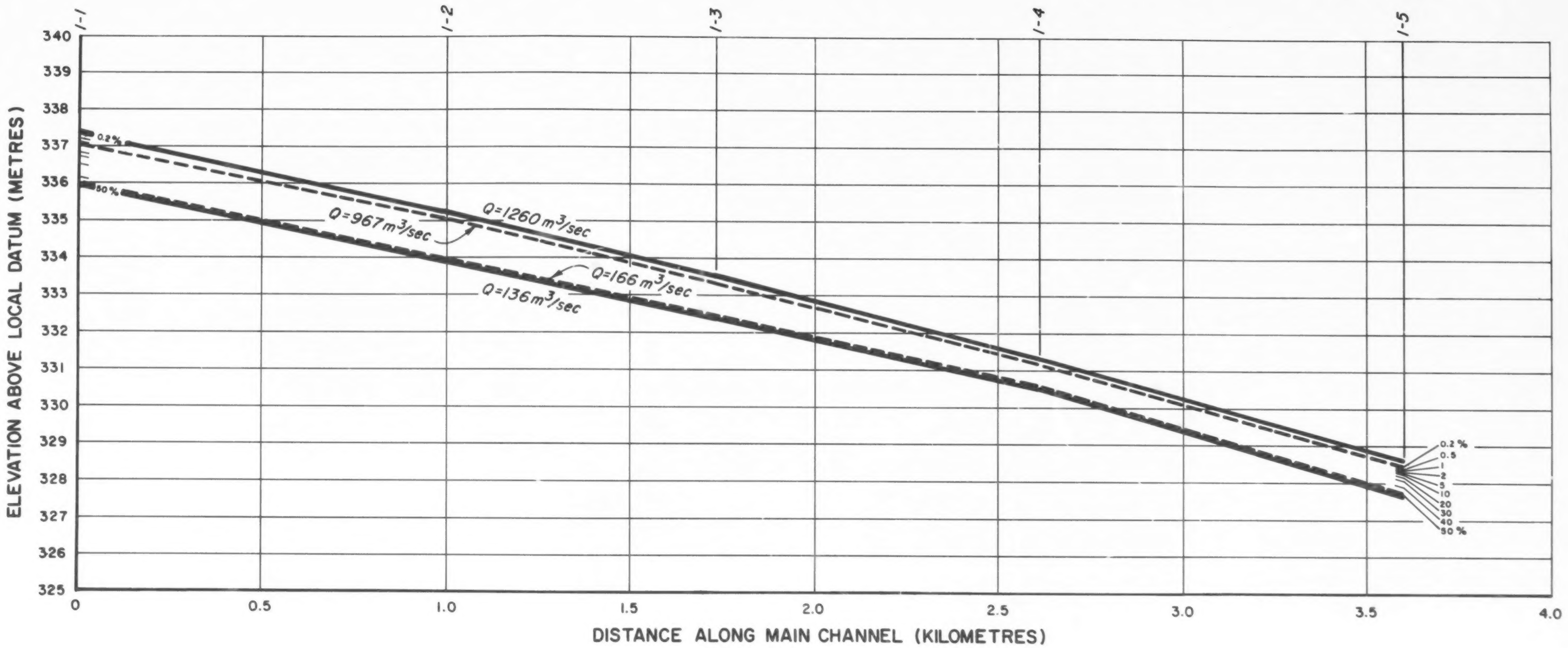
STIKINE - ISKUT FEASIBILITY STUDY

HYDROLOGY, RIVER REGIME & MORPHOLOGY
TEST REACH PROFILES

- SHEET 2 OF 4

DATE AUG 1980	**PLATE 5 - 12**
DWN C.Y.	DWG. No. 915 - C14 - C217

REPORT No. H-1110



UPPER ISKUT RIVER TEST REACH

NOT

1.

2.

3.

LEG

BRITI

STIKI

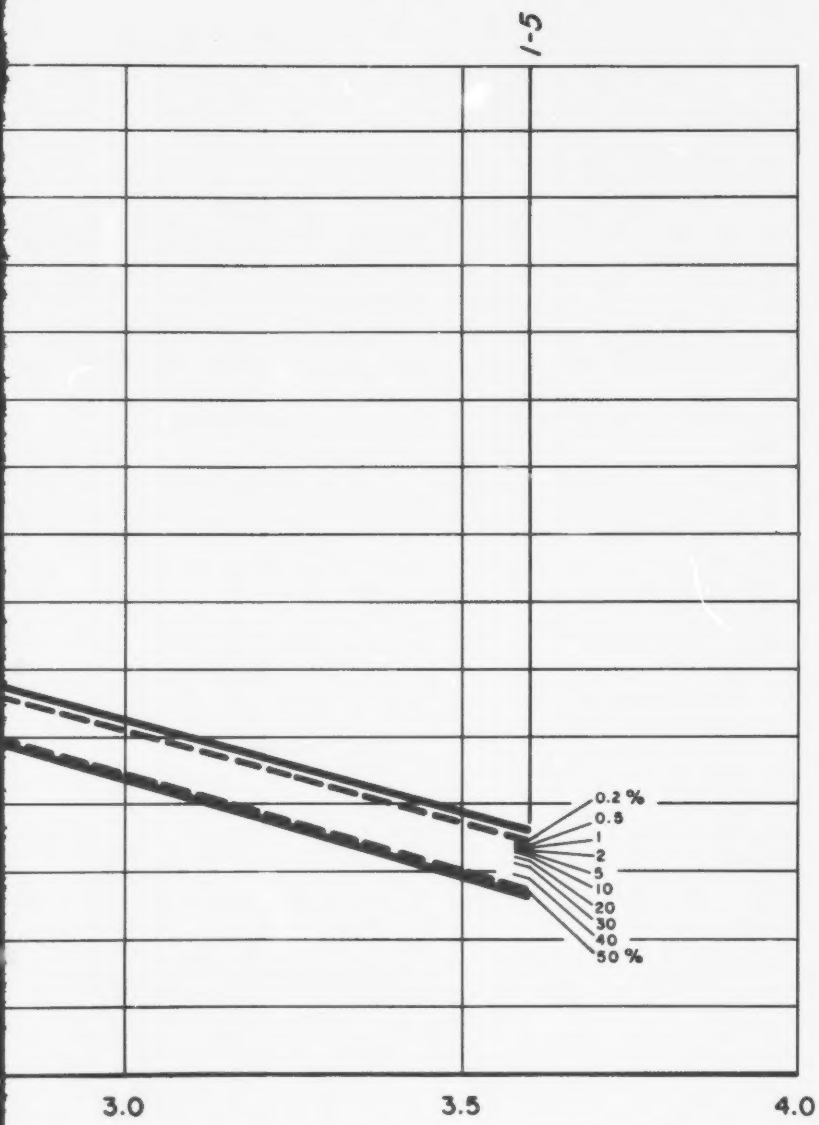
HYDR

TEST

DATE A

DWN

REPORT



NOTE:

1. FOR TEST REACH LOCATION SEE PLATE 2-1
2. FOR CROSS SECTION LOCATION AND CONFIGURATION SEE PLATE 5-5
3. WATER LEVELS SHOWN ARE FOR FLOWS OF INDICATED EXCEEDENCE PROBABILITIES DERIVED FROM FLOW DURATION ANALYSIS

LEGEND:

—— NATURAL CONDITIONS

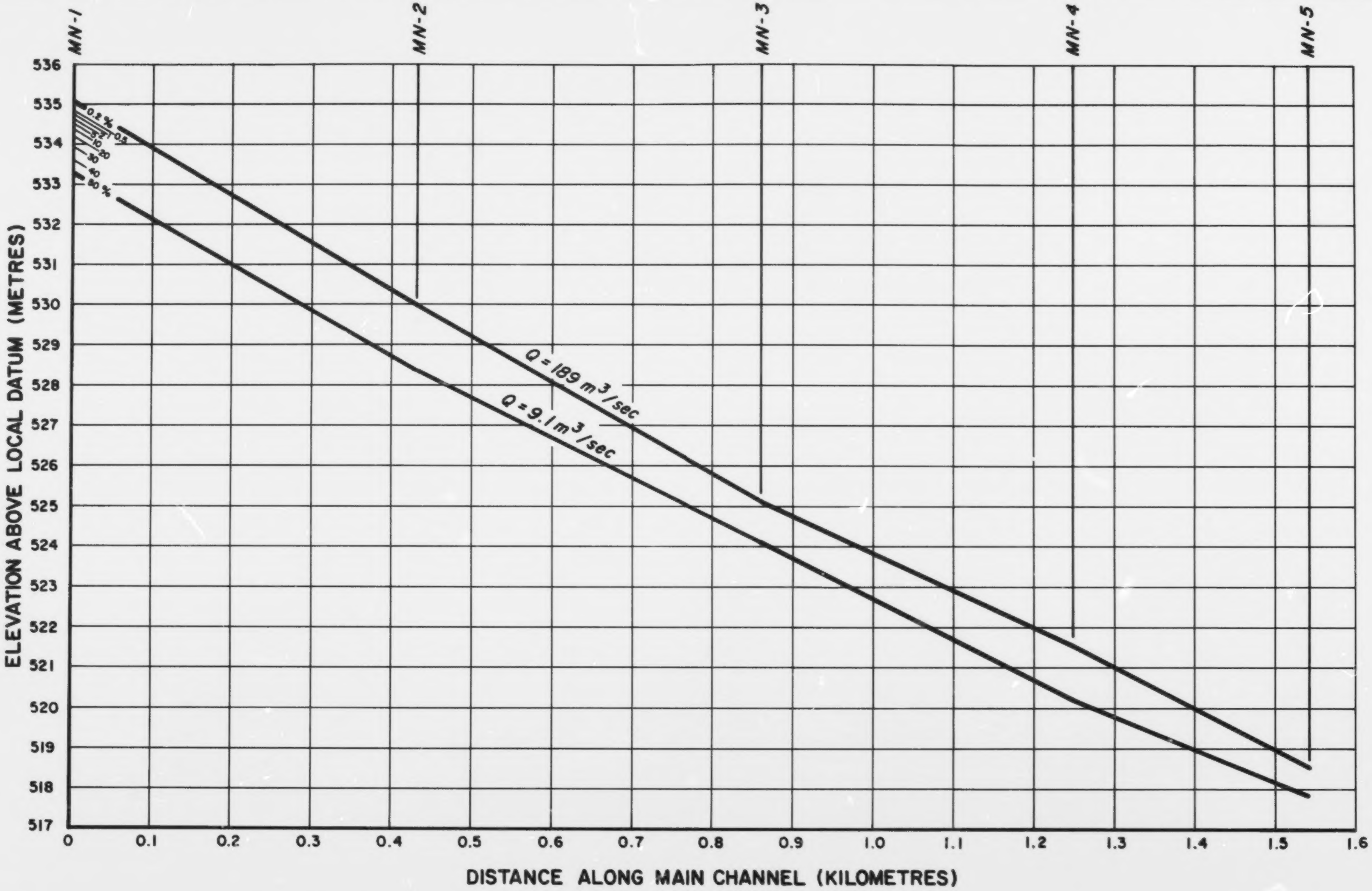
– – – REGULATED CONDITIONS

BRITISH COLUMBIA HYDRO AND POWER AUTHORITY

STIKINE - ISKUT FEASIBILITY STUDY
HYDROLOGY, RIVER REGIME & MORPHOLOGY
TEST REACH PROFILES
- SHEET 3 OF 4

DATE AUG 1980	**PLATE 5 - 12**
DWN C.Y.	DWG. No. 915 - C14 - C218

REPORT No. H-1110



MORE CREEK TEST REACH

NOTE:

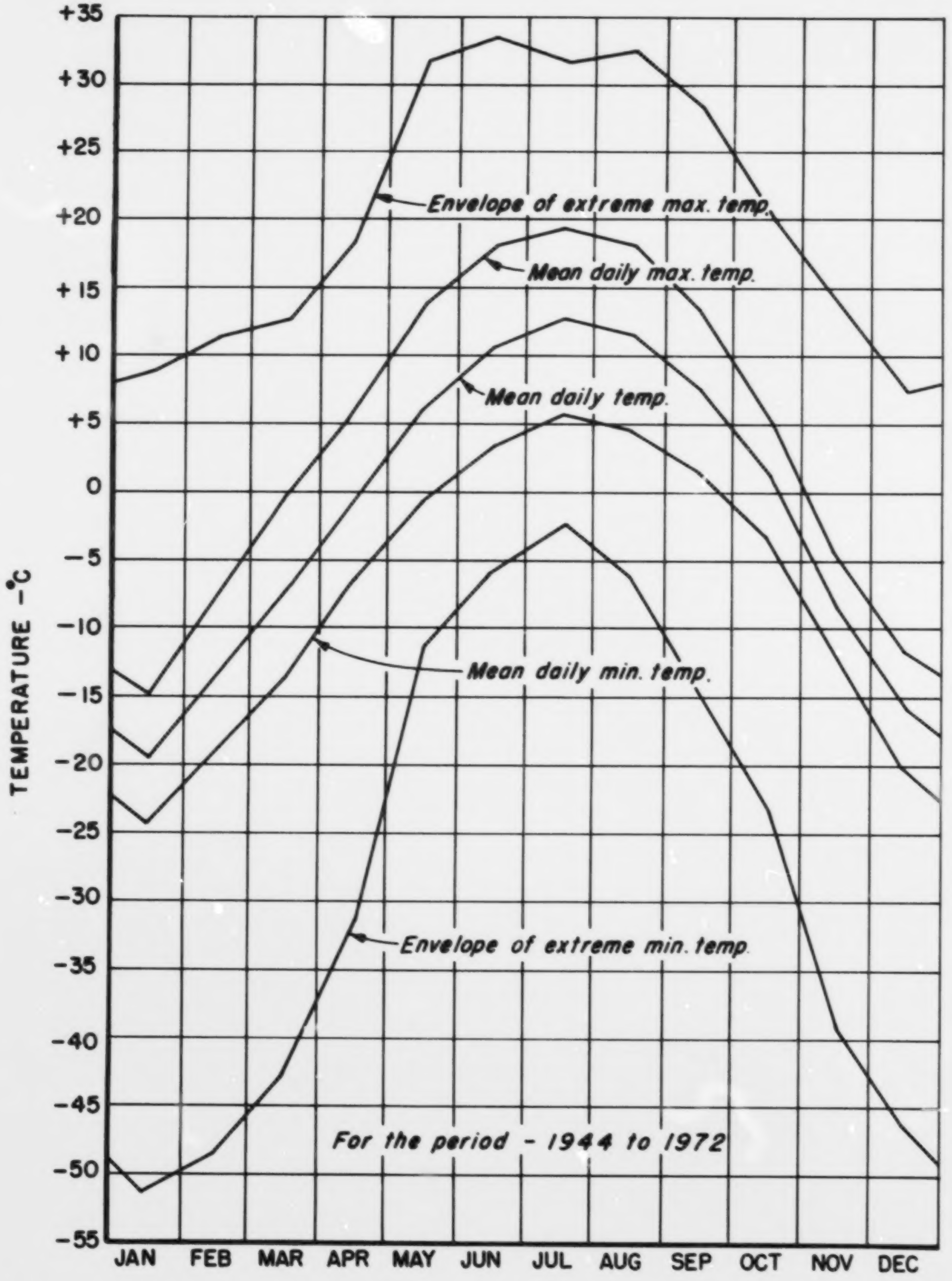
1. FOR TEST REACH LOCATION SEE PLATE 2-1
2. FOR CROSS SECTION LOCATION AND CONFIGURATION SEE PLATE 5-4
3. WATER LEVELS SHOWN ARE FOR FLOWS OF INDICATED EXCEEDENCE PROBABILITIES DERIVED FROM FLOW DURATION ANALYSIS

BRITISH COLUMBIA HYDRO AND POWER AUTHORITY

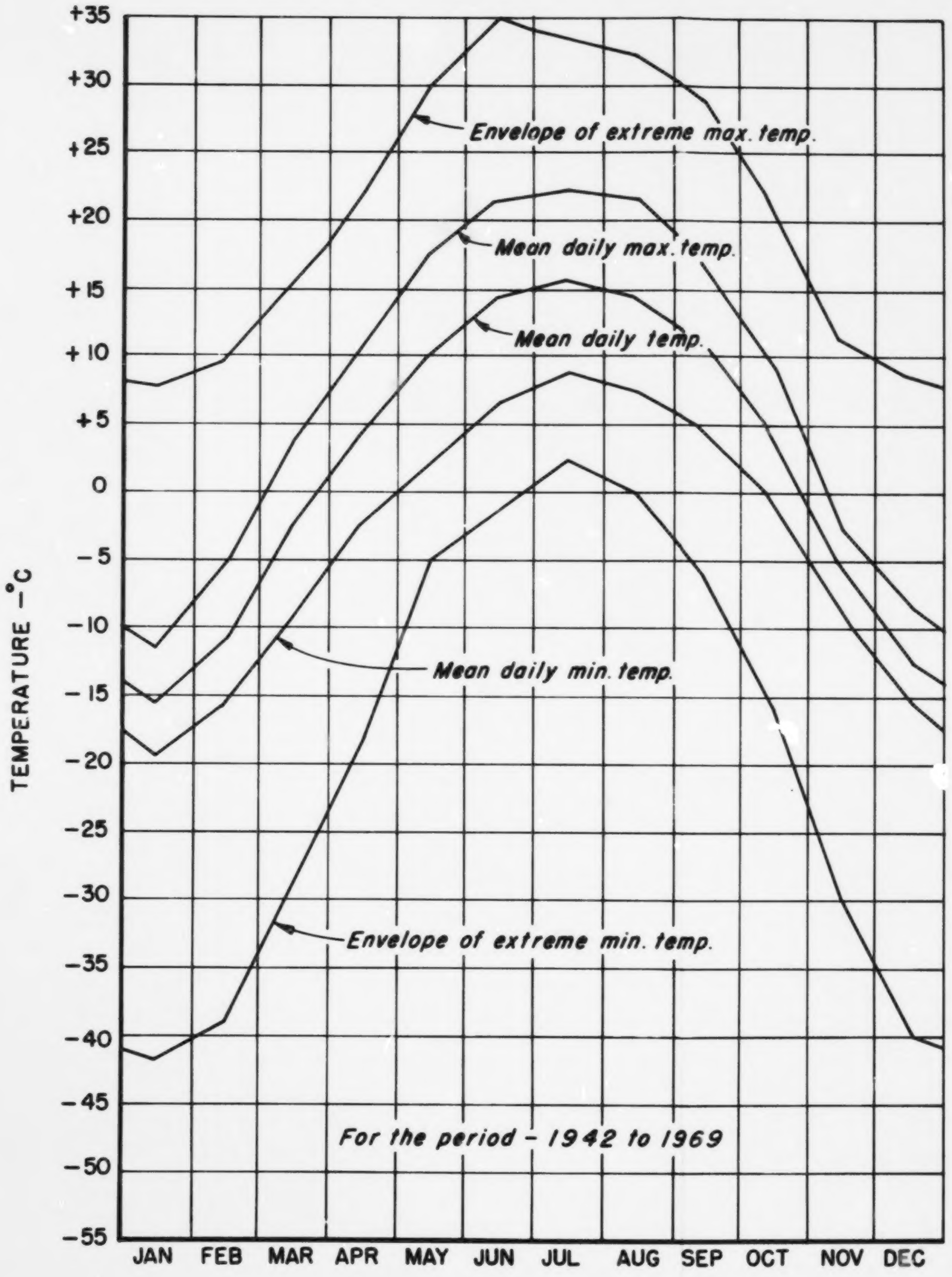
STIKINE - ISKUT FEASIBILITY STUDY
HYDROLOGY, RIVER REGIME & MORPHOLOGY
TEST REACH PROFILES
- SHEET 4 OF 4

DATE AUG 1980	PLATE 5 - 12
DWN G.C.	DWG No. 915 - C14 - C219

REPORT No. H-1110



DEASE LAKE



TELEGRAPH CREEK

NOTE:

THE TEMPERATUR
MONTHLY AVERAG
FOR EACH MID-M
CURVES ONLY AP
INFORMATION.

BRITISH COLUM

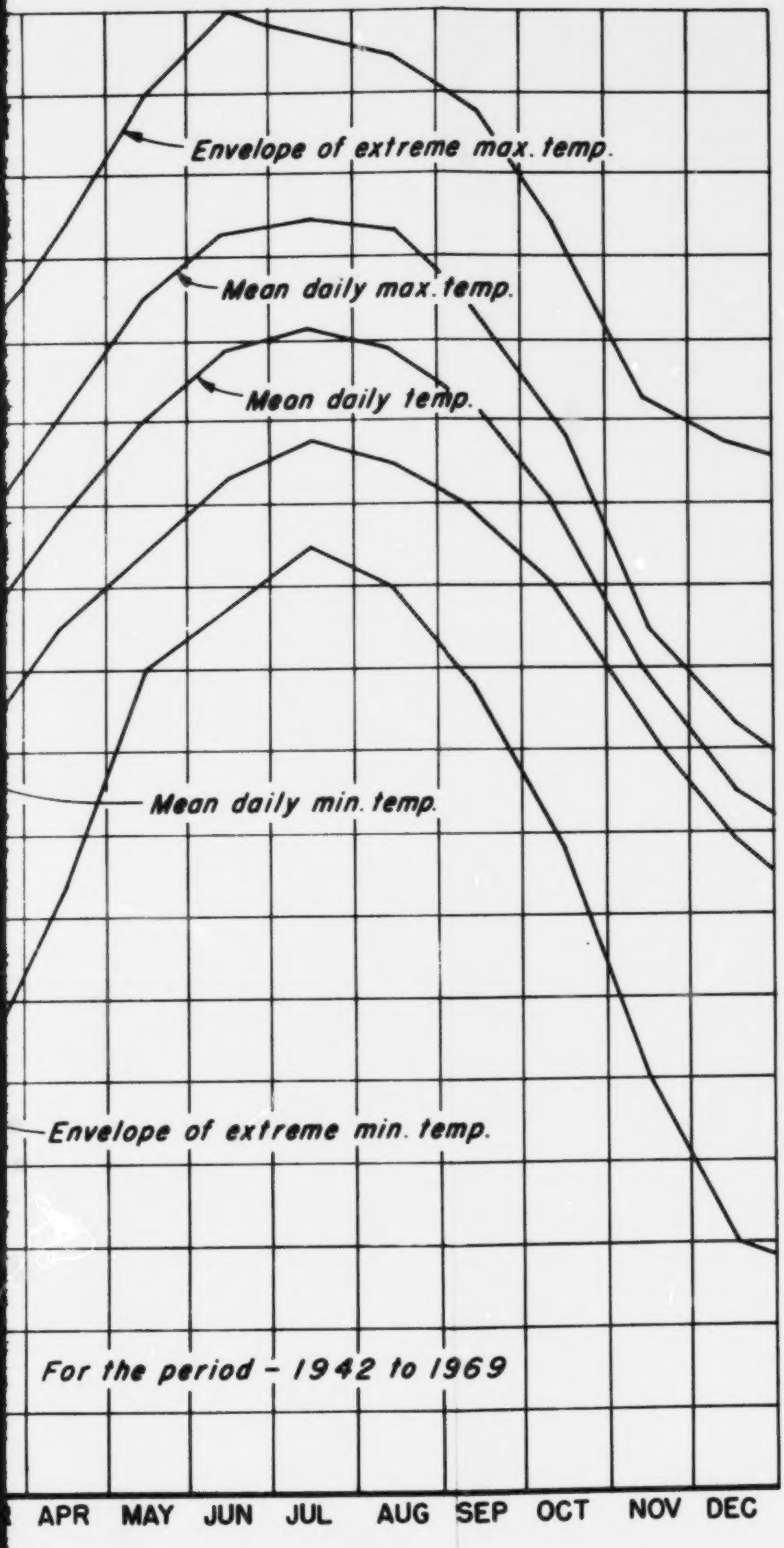
STIKINE - ISK

HYDROLOGY,
AIR TEMPE

DATE AUG 19

DWN N.M.

REPORT No. H-1110



TELEGRAPH CREEK

N O T E:

THE TEMPERATURE CURVES ARE PREPARED FROM MONTHLY AVERAGE OR EXTREME DATA PLOTTED FOR EACH MID-MONTH AND, ACCORDINGLY, THE CURVES ONLY APPROXIMATE DAILY TEMPERATURE INFORMATION.

BRITISH COLUMBIA HYDRO AND POWER AUTHORITY

STIKINE - ISKUT FEASIBILITY STUDY

HYDROLOGY, RIVER REGIME & MORPHOLOGY

AIR TEMPERATURE DATA

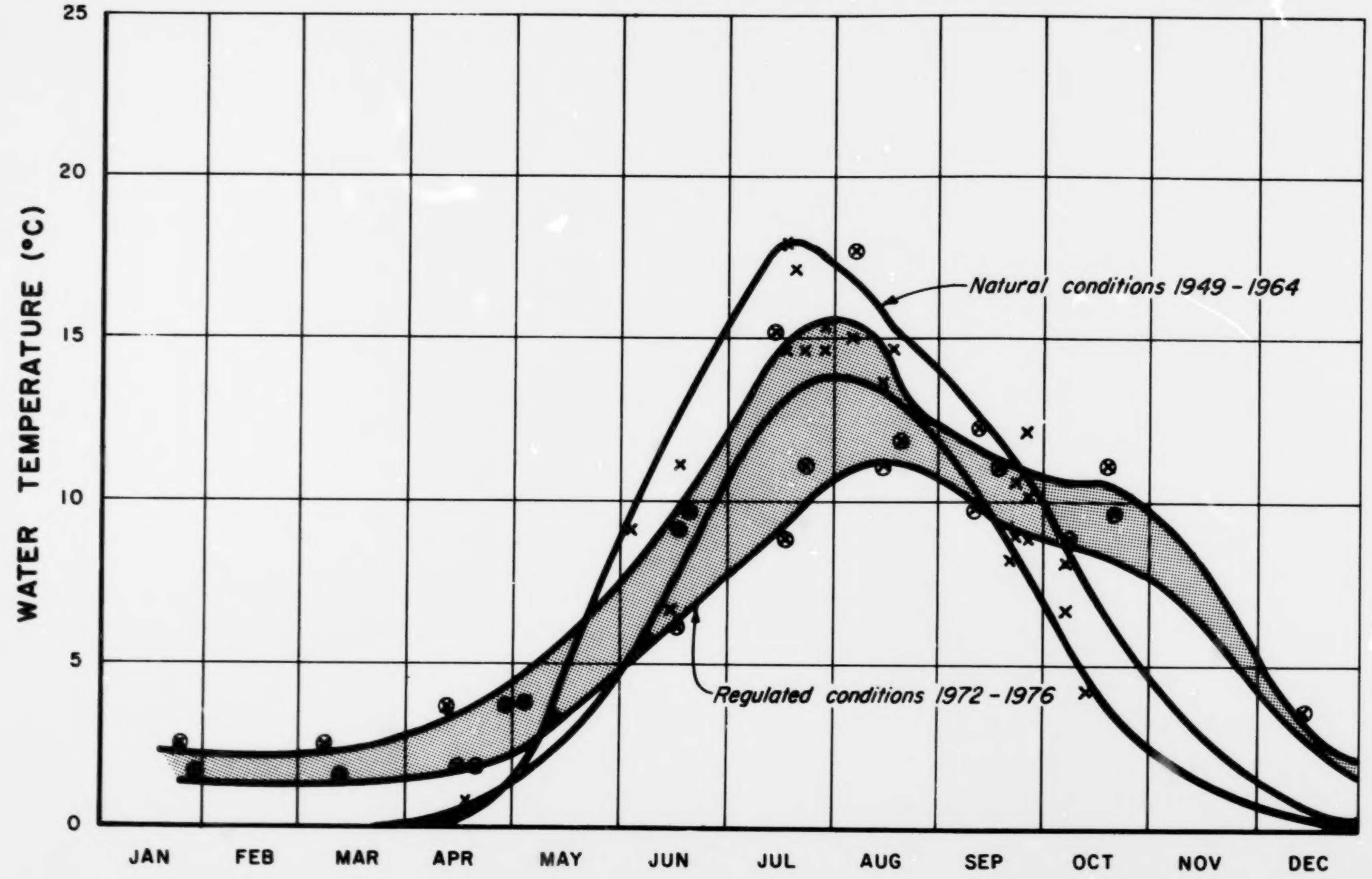
DATE AUG 1980

PLATE 6 - 1

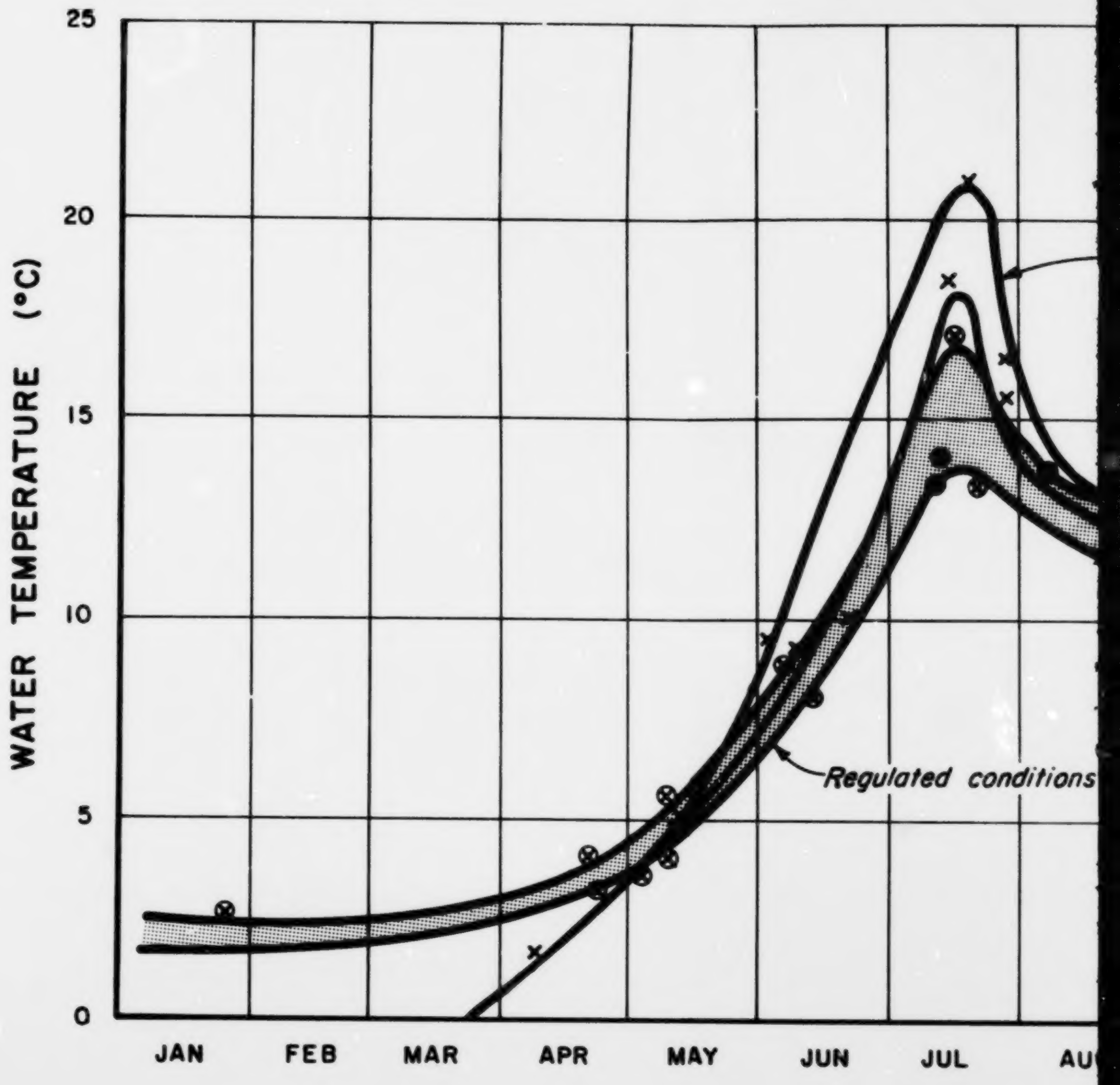
DWN N.M.

DWG. No. 915 - C14 - C220

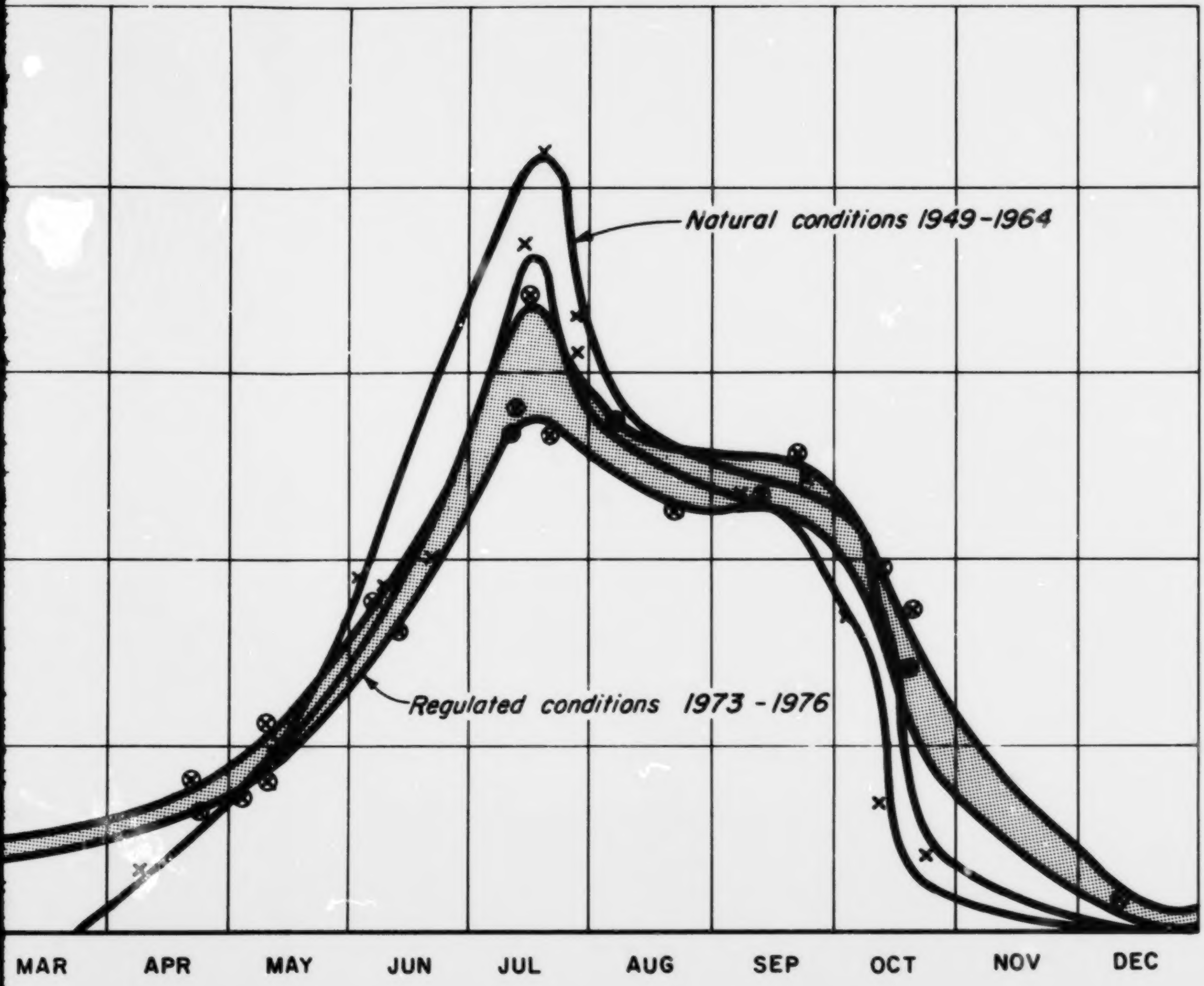
REPORT No. H-1110



PEACE RIVER AT HUDSON HOPE



PEACE RIVER NEAR TA



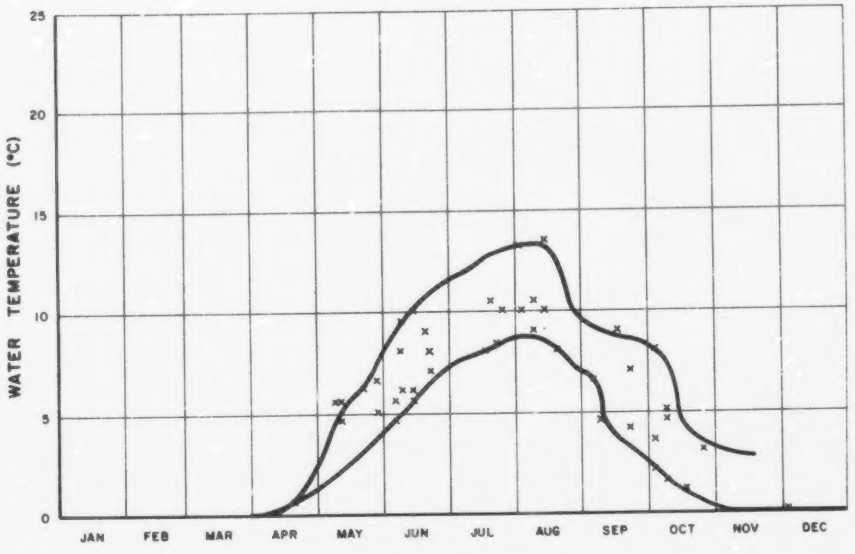
PEACE RIVER NEAR TAYLOR

BRITISH COLUMBIA HYDRO AND POWER AUTHORITY

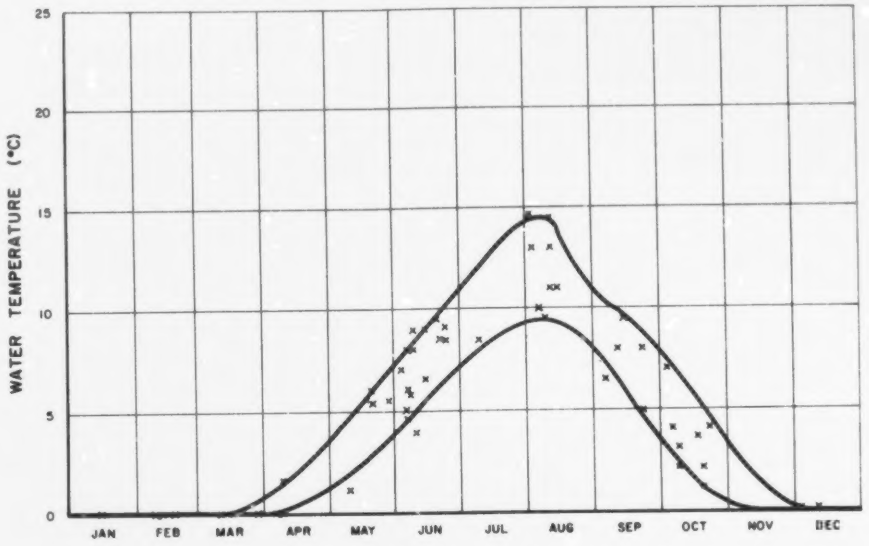
STIKINE - ISKUT FEASIBILITY STUDY
HYDROLOGY, RIVER REGIME & MORPHOLOGY
WATER TEMPERATURE ENVELOPES
PEACE RIVER BASIN

DATE AUG 1980	PLATE 6 - 2
DWN K.L.	DWG. No. 915 - C14 - C221

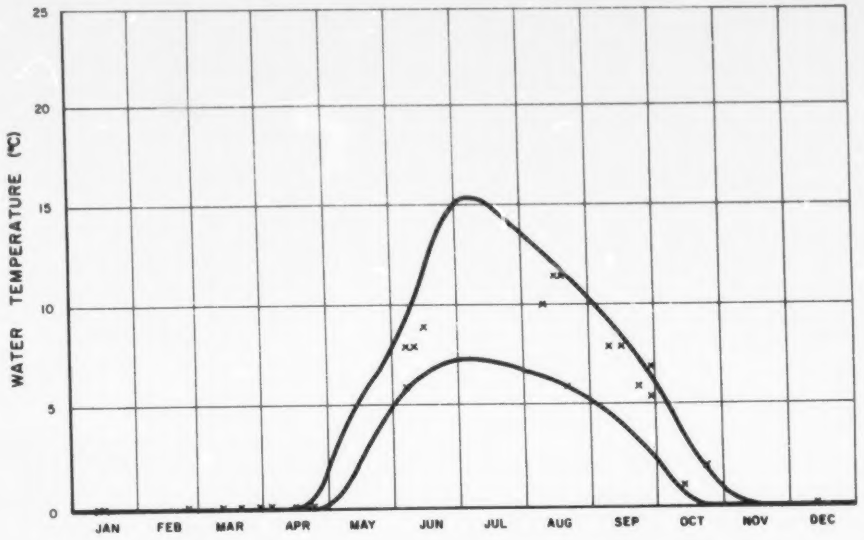
REPORT No. H-1110



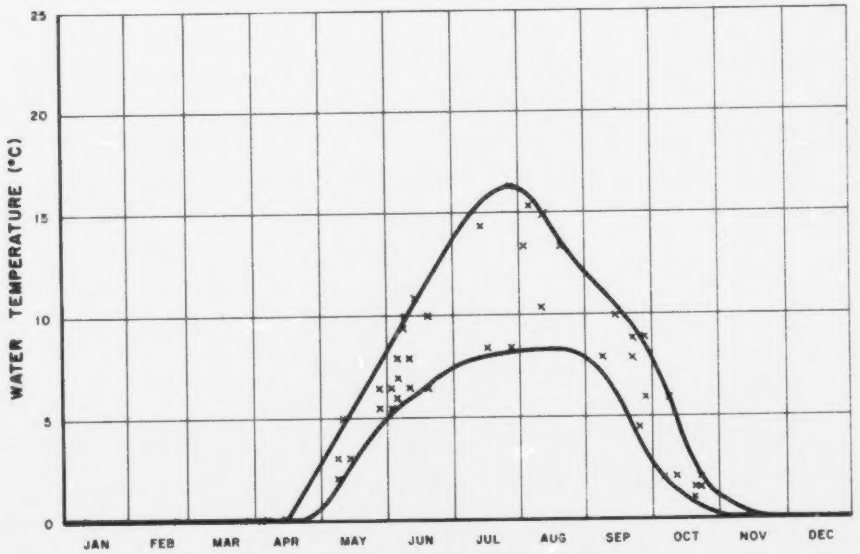
KLAPPAN RIVER NEAR TELEGRAPH CREEK



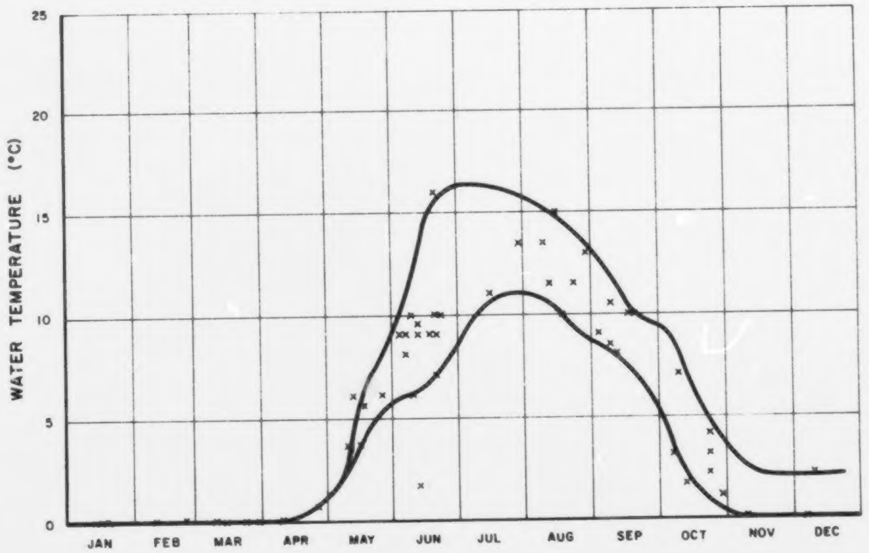
STIKINE RIVER ABOVE GRAND CANYON



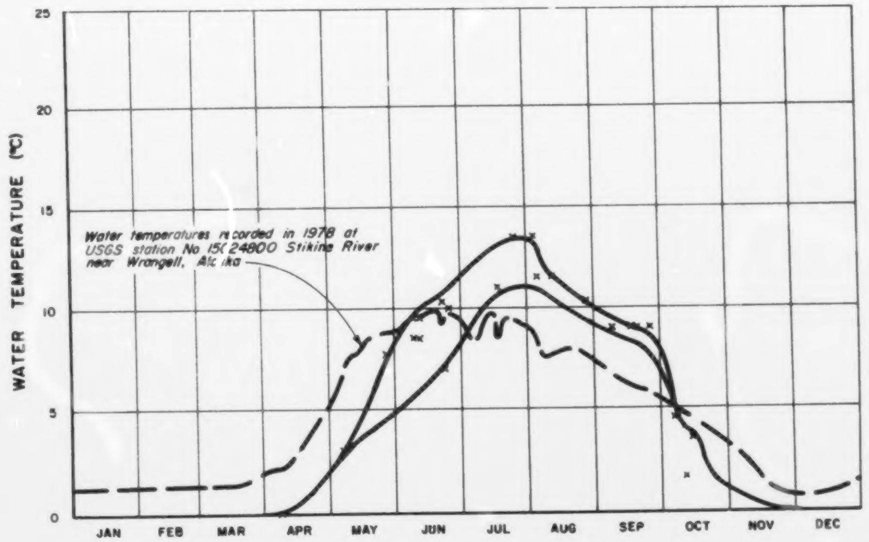
TANZILLA RIVER NEAR TELEGRAPH CREEK



TUYA RIVER NEAR TELEGRAPH CREEK



STIKINE RIVER AT TELEGRAPH CREEK



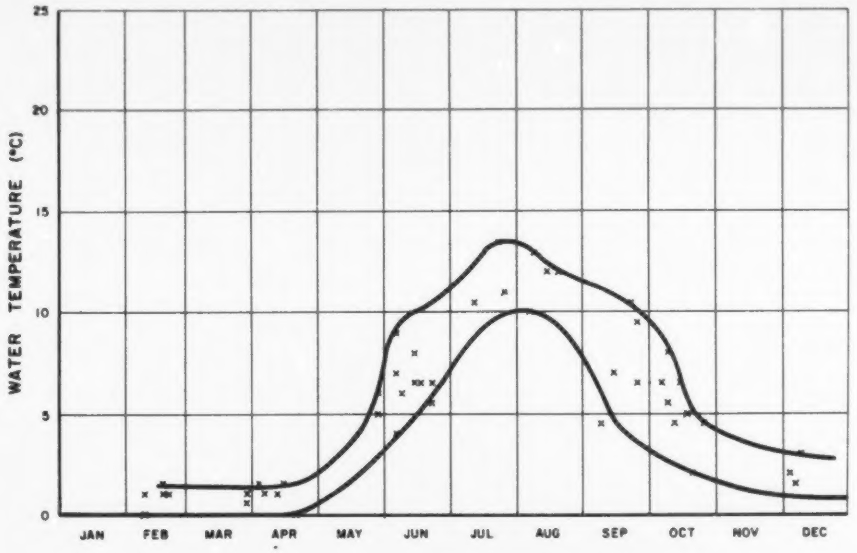
STIKINE RIVER ABOVE BUTTERFLY CREEK

BRITISH COLUMBIA HYDRO AND POWER AUTHORITY

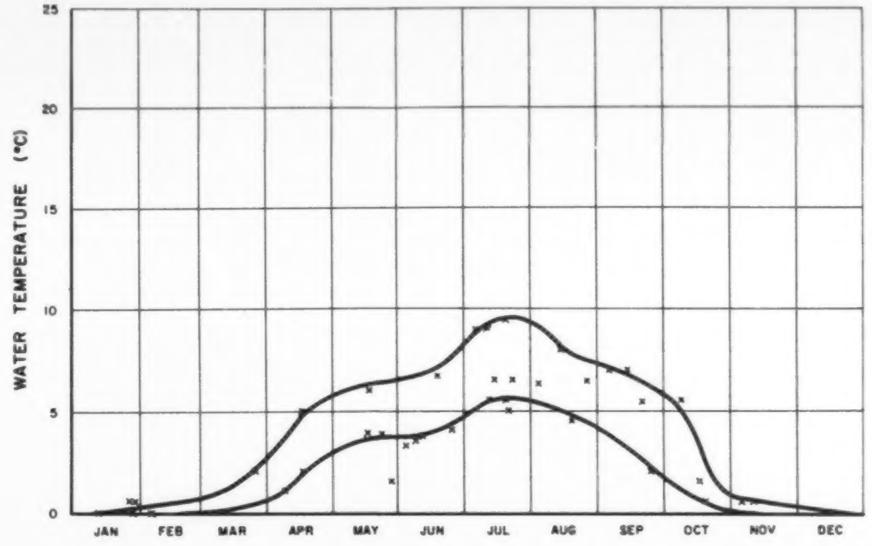
STIKINE - ISKUT FEASIBILITY STUDY
HYDROLOGY, RIVER REGIME & MORPHOLOGY
WATER TEMPERATURE ENVELOPES
STIKINE RIVER BASIN

DATE AUG 1980	PLATE 6 - 3	R
DWN K.L.	DWG No. 915 - C14 - D222	

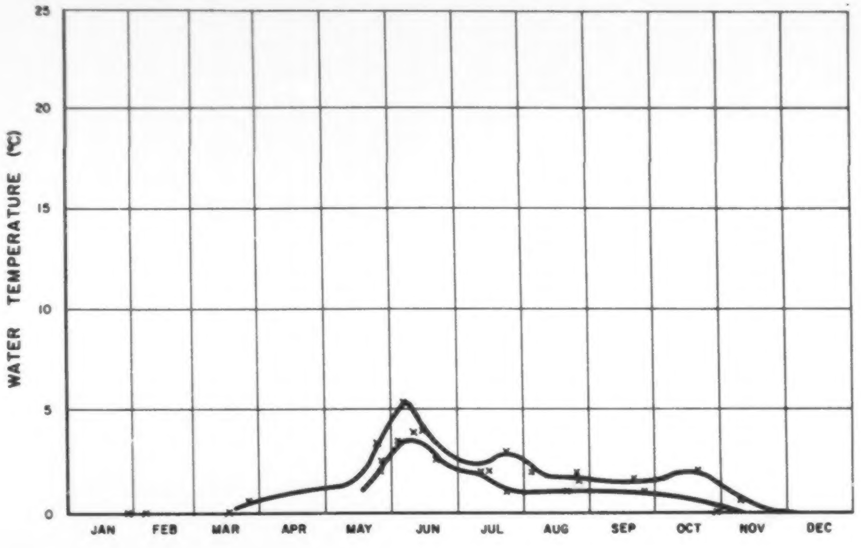
REPORT No. H-1110



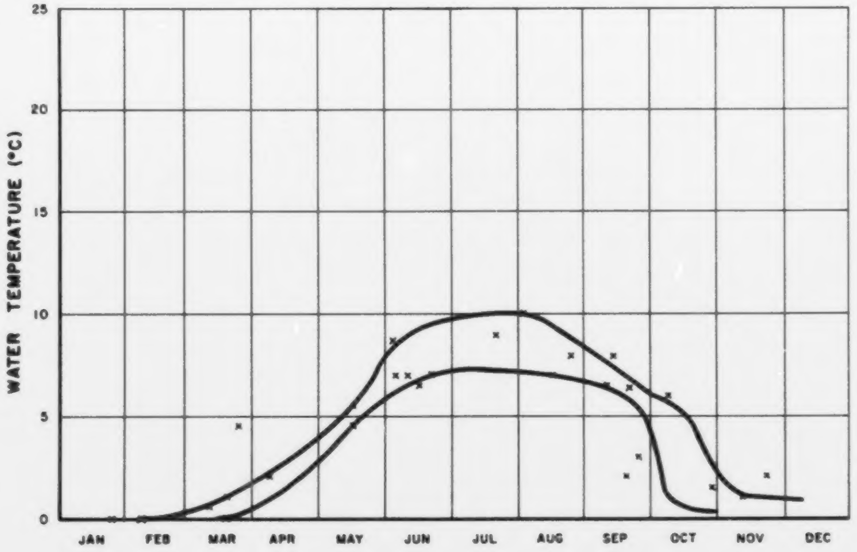
ISKUT RIVER AT OUTLET OF KINASKAN LAKE



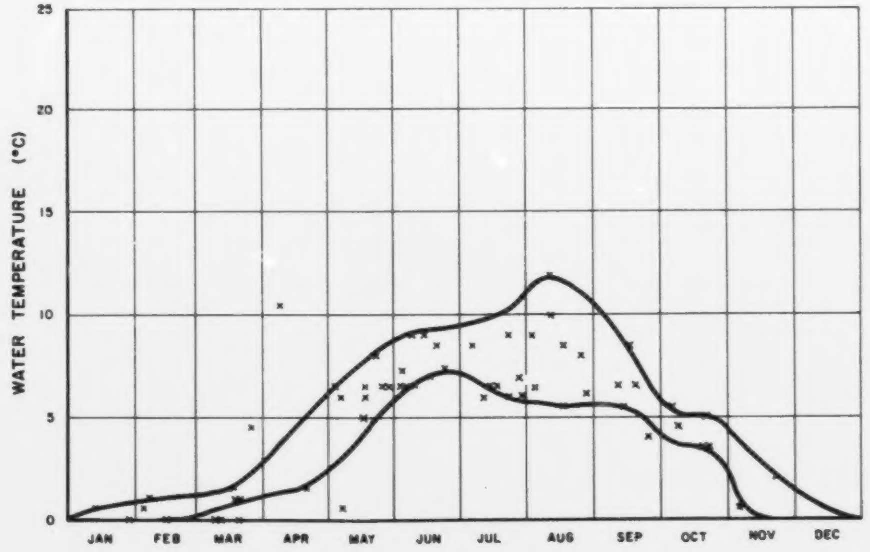
MORE CREEK NEAR THE MOUTH



FORREST KERR CREEK ABOVE 460 METRE CONTOUR



ISKUT RIVER ABOVE SNIPPAKER CREEK



ISKUT RIVER BELOW JOHNSON RIVER

BRITISH COLUMBIA HYDRO AND POWER AUTHORITY

STIKINE - ISKUT FEASIBILITY STUDY
HYDROLOGY, RIVER REGIME & MORPHOLOGY
WATER TEMPERATURE ENVELOPES
ISKUT RIVER BASIN

DATE AUG 1980	PLATE 6 - 4		R
DWN K.L.	DWG No. 915 - C14 - D223		

REPORT No. H-1110

PHOTOGRAPHS

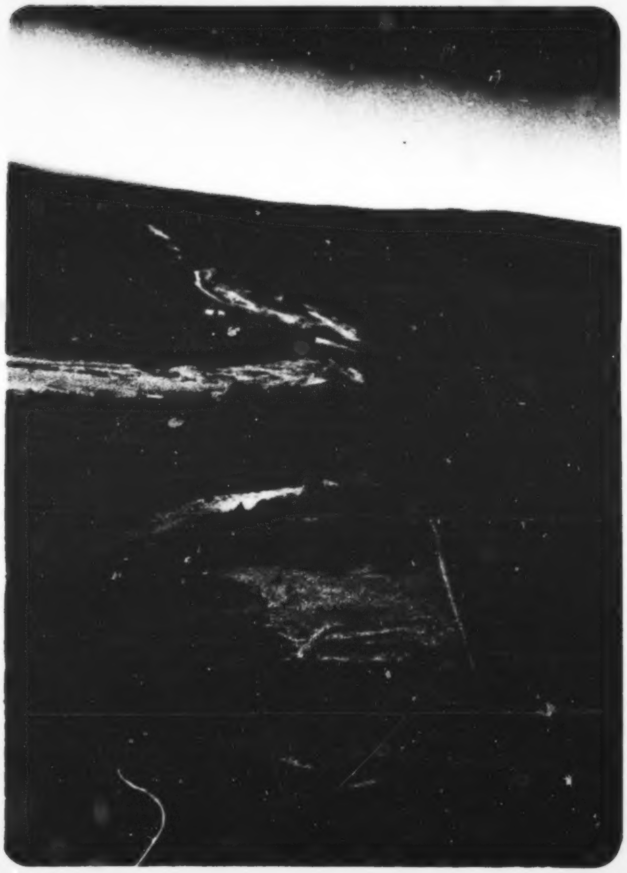


Photo #1

Upstream view along the Stikine River near the Upstream end of the Proposed Site Z Reservoir.

Photo #2

Grand Canyon of the Stikine River, upstream view.

Photo #3

Stikine River above Chutine River, upstream view.

Photo #4

Stikine River Lower Test Reach above the Scud River

Photo #5

Iskut River Upper Test Reach, upstream view.

Photo #6
Iskut Canyon, upstream view.

Photo #7
Iskut River below Iskut Canyon Damsite, upstream view.

Photo #8

Iskut River Lower Test Reach, downstream view.

Photo #9

More Creek, South Fork, upstream view.

Photo #10

Forrest Kerr Ck. Diversion Route, looking from Forrest Kerr Ck. towards the South Fork of More Ck.